Fundamentals of Economic Geography

Van Royen & Bengtson

FIFTH EDITION

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William Van Royen

Professor and Head, Department of Geography, University of Maryland
Editor and Author, Atlas of the World's Resources

Nels A. Bengtson

Late Professor of Geography and Dean of the University Junior Division,
Emeritus, University of Nebraska

Donald J. Patton and Walter Deshler *Collaborators*

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by William Van Royen and Nels A. Bengtson

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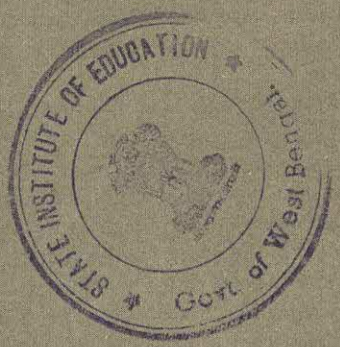
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Introduction to the Fifth Edition

THE FIFTH edition of this book differs to a considerable extent from the previous one. Only in Chapters 6, 13, 14, 17, and 30 have the changes been minor. All other chapters needed to be brought up to date, and considerable rewriting and reorganization proved to be desirable. The present Chapter 1 was considered to be a better introduction to the subject matter of the book. Chapter 19 was written as an introduction to the study of the mineral resources, as Chapters 6 and 7 constitute an introduction to the agricultural resources. Through a discussion of power utilization, Chapter 19 leads logically into the following discussions of water and water power, coal, petroleum and natural gas, and the nuclear energy minerals. The discussion of minerals and rocks of direct economic use has been moved from the beginning of the part of the book devoted to the mineral resources to its end. This appears to be a more logical sequence from an economic geographic point of view. Most of the maps, diagrams, and graphs required remaking and redrafting. A number of old ones have been omitted and new ones have been added. Also, many of the photographs have been replaced.

The former "Suggested Readings" at the end of each chapter have been changed almost completely. There are still "Suggested Brief Readings." These have been limited in general to geographical periodicals that are fairly easily accessible, and to articles that are pertinent to the chapter concerned. Since the book is used mostly in English-speaking countries, I hope my colleagues in other countries will forgive me for not including articles in French, German, Dutch, Italian, Russian, and other languages in which much important material pertaining to economic geography has been published.

For many chapters "Selected References" have been added. These are mostly a selection of works of reference and of important books, also fairly easily available, and suitable for the beginning student in geography. The reference sections of Chapters 7, 16, and 19 are quite extensive. Since it is not practical to keep a book on economic geography entirely up-to-date insofar as production and trade data are concerned, the user can find listed in these reference sections some of the basic and most easily accessible statistical sources for con-



sultation, if he should wish to view the latest data.

I hope sincerely that the many changes will make the book more useful to professors who may wish to use "Fundamentals of Economic Geography" as a textbook, and to those students and interested general readers who desire a geographic introduction to the study of the basic resources of our world.

It is with profound sorrow that this introduction is written in the first person singular. Dr. Nels A. Bengtson died suddenly before work on the Fifth edition could be completed. Rarely has collaboration on a book been as pleasant and successful as was ours, even though we have long been separated by half a continent. By the time we had completed the Third edition of this book neither Dr. Bengtson nor I would have found it easy to point out exactly what had been the work of each of us. Advanced age did not make it possible for Dr. Bengtson to participate in the preparation of the Fifth edition to the extent he had participated in that of previous editions. However, he was willing to undertake the rewriting of the present Chapter 23, which deals with the nuclear energy minerals. As changes in this field have been considerable since the Fourth edition, such was no easy task. It was completed successfully with the advice of Dr. Theodore Jorgenson, Professor of Physics at the University of Nebraska, and that of several members of the staff of the United States Atomic Energy Commission at Germantown, Maryland. The final responsibility for the chapter is mine and any opinions expressed therein are not to be attributed in any way or manner to the Atomic Energy Commission or to Dr. Jorgenson.

Dr. Bengtson also was willing to view critically all chapters revised and rewritten by me. In several instances his careful scrutiny caused me to make further changes and write additional paragraphs. Dr. Bengtson did not live to be able to do the same for the maps, diagrams, graphs, and photographs and their captions. As all final work has had to be mine, I am solely responsible for all errors of commission and omission.

The Fifth edition could not have been brought to completion without the help of a number of persons. In the first place I owe thanks to many users of previous editions who have been so kind to draw my attention to errors, who have pointed out omissions, or who have suggested improvements in organization. It is not possible to mention here by name all colleagues who have thus aided in improving the book, but I should like to thank in particular Professors Padgett and Clover for their many helpful suggestions.

As in the previous edition, Dr. Donald J. Patton of the Carnegie Institution of Washington has been responsible for the chapter on the geographic aspects of transportation and commerce. Dr. Walter W. Deshler of the University of Maryland has been very helpful in revising Chapters 8, 9, 11, 12, 15, and 24. Miss Bridget Nicolls, Research Associate in Geography at the University of Maryland, has aided in many ways, especially by rewriting and bringing up to date the chapter on the economic significance of the sea. Mr. Jeremy Anderson of the University of Maryland, a specialist in the geography of the Soviet Union, has advised on several aspects of the resources of that country. Mr. Alan Kolbo and Mr. Subramanian Moryadas, Research Assistants at the University of Maryland, have collected most of the basic statistical data needed for the revision of maps and graphs. Mr. Joseph Wiedel, Cartographer at the University of Maryland, has supervised the drafting, and he, Mr. Rameshwar Misra, Mr. Donald Lloyd, Mr. Donald Wirak, and Mr. Ronald Kuipers have done the cartographic work.

Finally, thanks should be extended to all those in government offices in Washington and elsewhere, in private corporations, and in embassies who have aided us with advice, data, and suitable photographs. The United States Departments of the Interior, Agriculture, and Commerce should be mentioned in particular.

The scope and purposes of the book are still as stated in the Third edition, from the Preface of which I quote the following paragraphs:

> Modern geography is partly a physical and partly a social science. It seeks, among other things, to relate facts of the natural environment to facts and problems of the socio-economic environment. In this respect geography is one of the few sciences that attempt to bridge the apparently widening gap between the physical and the social sci-

ences. Its position, although a difficult one, is of rapidly increasing importance in the modern world. Economic geography is a subdivision of social geography in the broadest sense.

This book has been written for all readers who are interested in economic geography. The phraseology, we trust, is clear and accurate and not unnecessarily technical. The book is not necessarily intended for the specialist in geography. We hope that the geographic approach to the complex problems of utilization of natural resources, including the problems of their conservation, will be of interest to readers in related fields, and to those who wish to have a realistic approach to today's world problems.

The main purpose of the book is to aid the reader in developing an understanding of the fundamentals of economic geography. Therefore, a few of the chapters are essentially of a physical geographic nature, although, wherever practical in these chapters, I have pointed toward economic geographic implications.

Students of economic geography, even if previously they have studied the physical aspects of geography, may profit from a brief exposition of major facts and principles that are basic to the understanding of economic geography. The old saying, "*Repetitio est mater studiorum*" is still as good as ever. For students who have not had such a background, the physical geographic material in this book can easily be supplemented in laboratory or combined "self-activity and quiz" sections.

The book treats economic geography from a general, systematic, or comparative point of view. Since the effects of climatic and related physical conditions upon the geographic distribution of the world's agricultural production are very pronounced, it has been found advantageous to base the chapters dealing with agricultural resources and activities upon a limited number of large-scale climatic regions as shown on the map at the end of the book. Printing of this map in colors has been considered, but a number of users have informed me that they find it more practical to let students hand-color the map as they proceed from Chapter 8 to Chapter 17.

The mineral resources are treated on a world basis, but with more emphasis upon Anglo-American conditions, as it was necessary to put a practical limit to the size of the book. The same applies to Chapter 28, which deals very briefly with the major types of manufacturing industries.

As has been said in the introductions to previous editions, the facts in the book and the relationships pointed out are intended to provide basic material for thought, and not merely items for memorization purposes. "Study without thought is wasteful. Thought without study is dangerous." (*Confucius*)

William Van Royen



3461

Contents

1

ECONOMIC ACTIVITIES AND THEIR PHYSICAL BACKGROUND 1

VARIETY OF ECONOMIC ACTIVITIES, 1 *Hunting and fishing Commercial hunting Commercial fishing Agriculture Forestry Mining and mineral exploitation Manufacturing and repair Transportation and communication Commerce Professional, public, personal, and domestic services* RELATIONSHIP BETWEEN ECONOMIC ACTIVITIES AND NATURAL OR PHYSICAL ENVIRONMENT, 10 RELATIONSHIP OF NATURAL LANDSCAPE TO CULTURAL LANDSCAPE, 10 *Location Landforms Water bodies Climate Land content Native vegetation Native animal life* SUGGESTED BRIEF READINGS, 16

2

DISTRIBUTION OF MANKIND: ITS SIGNIFICANCE AND ITS DYNAMIC ASPECTS 17

World population Distribution of world population PRESENT DISTRIBUTION OF POPULATION, 18 *The densely settled lands The thinly settled lands Causes of differences in population density Areas of intermediate population density Personal meaning of various densities Advantages and disadvantages of dense population Advantages and disadvantages of sparse population* ECONOMIC-GEOGRAPHIC EFFECTS OF HIGH AND LOW POPULATION DENSITIES, 26 PROBLEMS OF AREAS OF HIGH POPULATION DENSITY, 28 *More adequate resource utilization* CHANGES IN POPULATION AND POPULATION DISTRIBUTION, 29 SELECTED GENERAL REFERENCES, 31 OTHER SELECTED REFERENCES, 31 SUGGESTED BRIEF READINGS, 31

3

THE FIELD AND FUNCTION OF ECONOMIC GEOGRAPHY 32

POWER AND PRODUCTION, 33 *In the factory On the farm Transportation and economic distance* FACTORS OF PRODUCTION, 35 THE IMPORTANCE OF NATURAL RESOURCES, 35 MAN

AND THE NATURAL ENVIRONMENT, 35 *The importance of a differentiated natural environment* REGIONAL PRODUCTION DIFFERENCES, 36 *Differences in capacity of production Differences in stage of technical development* SPECIALIZATION OF HUMAN ACTIVITIES, 40 THE IMPORTANCE OF GEOGRAPHIC STUDIES, 41 THE PROBLEMS OF PROGRESS, 41 SELECTED REFERENCES, 41 SUGGESTED BRIEF READINGS, 41 MAJOR HANDBOOKS ON ECONOMIC GEOGRAPHY, 43 PRINCIPAL PERIODICALS CONTAINING ARTICLES OF AN ECONOMIC-GEOGRAPHIC NATURE, 43

4

THE EARTH AS THE HABITAT OF MAN 44

EARTH SPHERES, 45 *The atmosphere The hydrosphere The lithosphere* THE FOUNDATION MATERIALS, 46 *Minerals Rock Bedrock and mantle rock* THE MOST SIGNIFICANT COMMON ROCKS, 49 *Classes of bedrock* INTERNAL FORCES AND LANDFORMS, 52 THE MAJOR LANDFORMS, 54 *Plains Hilly lands Plateaus Mountains* EXTERNAL FORCES AND LANDFORMS, 58 *Rock decay or weathering Erosion and deposition* MAPS, 66 MAJOR LANDFORMS OF THE CONTINENTS, 66 *North America South America Africa Europe Asia Australia and New Zealand* MOUNTAINS AND ECONOMIC ACTIVITIES, 69 THE PLAINS OF THE WORLD, 71 SELECTED REFERENCES, 71

5

FACTORS RESPONSIBLE FOR CLIMATIC DIFFERENCES 72

WEATHER AND CLIMATE, 72 MAJOR FACTORS AFFECTING WEATHER AND CLIMATE, 73 *Radiation and insolation The effects of rotation upon heat distribution* ELEMENTS OF WEATHER AND CLIMATE, 78 *Temperature Air or barometric pressure and winds Humidity Precipitation* SUMMARY, 93 SELECTED REFERENCES, 94 SUGGESTED BRIEF READINGS, 94

6

CLIMATES OF THE WORLD: CLASSIFICATION AND DISTRIBUTION 95

CLASSIFICATION OF CLIMATE, 95 *The major climatic zones Effects of large water and land masses Effects of altitude* CLIMATIC TYPES, 99 THE MAJOR CLIMATES OF THE WORLD, 99 *The tropical climates The subtropical climates The intermediate climates The polar climates The mountain or high altitude climates* SELECTED REFERENCES, 104 SUGGESTED BRIEF READINGS, 104

7

CLIMATE, SOILS, AND AGRICULTURE 105

FACTORS THAT INFLUENCE AGRICULTURAL PRODUCTION, 105 *Psychological and sociological factors Economic factors Physical geographic factors* VEGETATION FORMATIONS OF THE WORLD, 107 *1. Evergreen tropical rain forest 2. Evergreen subtropical forests and bush 3. Cold deciduous or dry-deciduous forests 4. Coniferous forests 5. Savannas 6. Prairies 7. Steppes 8. Tundras 9. Shrub 10. Desert* THE NATURE OF SOILS, 110 CHARACTERIS-

TICS OF SOILS, 110 *Soil stratification Soil development* MAJOR SOIL GROUPS, 112 *1. Tundra soils 2. Podzols 3. Gray-brown podzolic soils 4. Prairie soils 5. Chernozems 6. Chestnut and brown soils 7. Yellow and red humid subtropical soils 8. Lateritic soils 9. Sierozems and desert soils* SOIL CONSERVATION AND MAINTENANCE, 116 DIRECT RELATIONSHIPS BETWEEN CLIMATE AND AGRICULTURAL PRODUCTION, 116 SELECTED GENERAL REFERENCES FOR CHAPTER 7 AND FOR CHAPTERS 8 TO 15, 118 OTHER SELECTED REFERENCES, 118 SUGGESTED BRIEF READINGS, 118

8

THE REGIONS OF HUMID TROPICAL CLIMATES: CHARACTERISTICS OF THE THREE TYPES 119

THE TROPICAL RAINY TYPE OF CLIMATE, 121 *Temperature characteristics Pressure and winds Rainfall and humidity Native plant and animal life The soils of the rainy tropics Agriculture* THE TROPICAL SAVANNA TYPE OF CLIMATE, 130 *Winds Temperature Rainfall Tropical Tropical cyclones Native vegetation Native fauna Soils Agriculture* THE TROPICAL HIGHLAND TYPE OF CLIMATE, 134 *Essential characteristics Native flora Soils Agriculture and white settlement* SELECTED REFERENCES, 136 SUGGESTED BRIEF READINGS, 136

9

MAJOR AGRICULTURAL PRODUCTS OF THE HUMID TROPICS 137

BANANAS, 138 *Climate and soil conditions Principal commercial species Localization and international trade Commercial production Harvesting and marketing* CACAO, 141 *Production Distribution International trade* TROPICAL VEGETABLE OILS, 144 *The coconut palm Commercial production Oil palm* RUBBER, 148 *Change from gathering to estate agriculture Estates in the Far East* SUGAR CANE, 152 *Climatic conditions Production and distribution* COFFEE, 156 *Natural conditions favorable for coffee culture Present distribution of the coffee industry International trade in coffee* SPICES, 160 *Distribution* MEDICINAL PRODUCTS, 161 TROPICAL WOODS, 162 *Commercial production Distribution* CATTLE KEEPING, 164 SUGGESTED BRIEF READINGS, 166

10

THE REGIONS OF DRY TROPICAL CLIMATES: AREAS OF AGRICULTURAL POTENTIAL 167

THE TROPICAL STEPPES, 169 *General characteristics Native vegetation and animal life Soils* THE WARM DESERTS, 172 *General characteristics Native vegetation Soils Utilization of tropical steppe and desert lands Date production The camel Desert mode of life* SELECTED REFERENCES, 181 SUGGESTED BRIEF READINGS, 181

11

THE REGIONS OF MEDITERRANEAN CLIMATE: UNIQUE CHARACTERISTICS AND TYPICAL PRODUCTS 182

DISTRIBUTION AND CHARACTERISTICS OF THE MEDITERRANEAN CLIMATE, 183 *Rainfall and temperature Winds Native vegetation Soils* AGRICULTURE, 188 *Grain agriculture Animal industries Special agricultural products: fruits and vegetables Olives Dried fruits The citrus fruits Orange production Other crops Early fruits and vegetables* CONCLUSION, 200 SELECTED REFERENCES, 201 SUGGESTED BRIEF READINGS, 201

12

THE REGIONS OF HUMID SUBTROPICAL CLIMATE: AREAS OF TRANSITION 202

CHARACTER AND DISTRIBUTION OF HUMID SUBTROPICAL CLIMATE, 202 *Temperature Winds Rainfall Native vegetation Soils* LAND UTILIZATION, 206 *Crops Livestock* COTTON, 208 *Climatic requirements Historical significance Types of cotton Principal cotton regions Cotton in the United States Other cotton-producing countries International trends Centers of consumption of raw cotton* PEANUTS, 215 VEGETABLES AND SUBTROPICAL FRUITS, 217 *Grapefruit* RICE, 218 *Distribution of production Methods of production World production and international trade* TEA, 223 *Historical development Distribution and commercial production* SELECTED REFERENCES, 226 SUGGESTED BRIEF READINGS, 226

13

THE INTERMEDIATE CLIMATIC REGIONS—I: CHARACTERISTICS OF THE HUMID TYPES 227

THE HUMID CONTINENTAL CLIMATE, 229 *Temperature Winds and storms Precipitation Native vegetation Soils General aspects of land utilization* THE EAST COAST CONTINENTAL CLIMATE, 235 *Temperature Winds Rainfall and humidity Vegetation Soils Land utilization* THE WEST COAST MARINE TYPE OF CLIMATE, 237 *Temperature Winds Rainfall Native vegetation Soils Land utilization* THE SUBPOLAR TYPE OF CLIMATE, 239 *Temperature Winds and storms Humidity and precipitation Native vegetation Soils Land utilization* SELECTED REFERENCES, 243 SUGGESTED BRIEF READINGS, 243

14

THE INTERMEDIATE CLIMATIC REGIONS—II: CHARACTERISTICS OF THE SEMIARID AND ARID TYPES 244

THE INTERMEDIATE SEMIARID TYPE OF CLIMATE, 244 *Temperature Winds Humidity and rainfall Soils Native vegetation Land utilization* THE INTERMEDIATE ARID TYPE OF CLIMATE, 250 *Climatic conditions Vegetation Land utilization* SELECTED REFERENCES, 253 SUGGESTED BRIEF READINGS, 253

15
PRINCIPAL AGRICULTURAL PRODUCTS OF THE INTERMEDIATE REGIONS 254

WHEAT, 255 *Climatic adaptability of wheat The planting season—winter and spring wheats Moisture requirements Soil requirements Colonization of the temperate grasslands Principal wheat-producing regions Wheat in North America—limits of wheat cultivation Wheat in Argentina—climate and soils Wheat production in Europe and elsewhere Wheat yields Wheat as a commodity of international trade* RYE, 265 *Rye as a crop of poor soils* CORN, 265 *Importance of corn to American colonists Westward expansion of corn production in the United States The American Corn Belt Important types of corn Corn in Argentina Corn in Europe Other corn regions* BARLEY, 272 *Uses and qualities Range and centers of production International trade* OATS, 273 *Production and distribution* SOYBEANS, 274 *Commercial importance* SUGAR BEETS, 275 *Climatic requirements Principal beet-growing districts Intensive culture Beet sugar versus cane sugar* TOBACCO, 277 *The influence of soils Curing of tobacco Tobacco in the United States Tobacco in Europe and the Near East Other tobacco-producing centers Tobacco in international trade* LIVESTOCK, 281 HORSES, 281 *Distribution* CATTLE, 282 *Cattle raising The beef industry in the United States South America Australia and New Zealand Europe The localization of beef and dairy industries* SWINE, 286 *Distribution* SHEEP, 286 *Sheep in the United States International trade* SELECTED REFERENCES, 287 SUGGESTED BRIEF READINGS, 287

16
FORESTS AND FOREST INDUSTRIES IN THE INTERMEDIATE REGIONS 289

FORESTS, 289 *Deforestation The northern coniferous forests* LUMBERING, 290 *Principal centers of forest exploitation Timber resources and forest exploitation in the United States Timber resources and forest exploitation in Canada World lumber trade* WOOD PULP AND PAPER, 296 *Pulp production* FURS, 298 *Principal fur-producing countries Fur farming* SELECTED GENERAL REFERENCES, 299 OTHER SELECTED REFERENCES, 299 SUGGESTED BRIEF READINGS, 299

17
THE REGIONS OF POLAR CLIMATES: AREAS OF LIMITED POTENTIALS 300

THE TUNDRA CLIMATE, 300 *Climatic conditions Resources Human activities Economic significance of the tundra* THE ICECAP CLIMATE, 304 SELECTED REFERENCES, 305 SELECTED BRIEF READINGS, 305

18

THE ECONOMIC SIGNIFICANCE OF THE SEA: PRESENT AND POTENTIAL 306

DISTRIBUTION OF MARINE LIFE, 306 DISTRIBUTION AND USE OF FISH, 307 TYPES AND METHODS OF FISHING, 307 *Methods of catching fish Marketing problems Fishing ports Problems of conservation* THE MAJOR FISHING AREAS, 311 *The Northwest Pacific The Northwest Atlantic The Northeast Atlantic The Northeast Pacific Tropical seas Areas of considerable potential* OTHER MARINE RESOURCES, 317 *The whaling industry Fur seals Other resources* SELECTED GENERAL REFERENCES, 318 OTHER SELECTED REFERENCES, 318 SUGGESTED BRIEF READINGS, 318

19

INTRODUCTION TO THE MINERAL RESOURCES: PECULIAR CHARACTERISTICS OF MINERAL EXPLOITATION 320

LAND CONTENT, 320 MINERAL RESOURCES, 320 *Major groups of minerals Ores Modes of occurrence of mineral resources Geographic distribution of mineral resources Mineral exploitation* ROLE OF THE POWER MINERALS, 327 *Earliest power resources Human slaves as power resources* FURTHER POWER DEVELOPMENT AS EXEMPLIFIED BY THE UNITED STATES, 328 *The preindustrial era of colonial days in the New World The ascendancy of steam power, 1840-60 The importance of capital and inventiveness The supremacy of steam and the advent of electricity, 1860-1910 The age of distributable power, 1910 to the present* FUNDAMENTAL RESOURCES ESSENTIAL TO INDUSTRIAL PROGRESS, 335 SELECTED GENERAL REFERENCES FOR CHAPTER 19 AND FOR CHAPTERS 20-27, 335 OTHER SELECTED REFERENCES, 336 SUGGESTED BRIEF READINGS, 336

20

WATER AS A COMMODITY AND A SOURCE OF POWER 337

POROSITY AND PERMEABILITY OF ROCKS, 337 GROUND-WATER RESOURCES, 338 STREAMS AS SOURCES OF POWER, 340 *Characteristics of streams favorable for water-power development River regime* MECHANICS OF DEVELOPMENT OF WATER POWER, 341 POTENTIAL WATER-POWER REGIONS OF THE WORLD, 345 *Formerly glaciated areas High mountain areas Rainy tropics* DEVELOPMENT OF WATER POWER IN THE UNITED STATES, 346 *Water-power regions in the United States* WATER-POWER DEVELOPMENT IN EUROPE, 351 OTHER REGIONS OF WATER-POWER DEVELOPMENT, 355 *Water power in Asia Water power in Africa Water power in South America Water power in Oceania* WATER POWER AND INDUSTRY, 356 *The problem of long-distance transmission Cost of water power* SELECTED REFERENCES, 357 SUGGESTED BRIEF READINGS, 357

21

COAL—A KING DETHRONED? 358

GENERAL ECONOMIC POSITION OF COAL, 359 NATURE AND MODE OF ORIGIN OF COAL, 360 THE IMPORTANT CONSTITUENTS OF COAL, 361 *Leading uses of*

coal KINDS OF COAL, 362 *Peat Lignite Subbituminous Bituminous The role of coke in industry Semibituminous Semianthracite Anthracite or hard coal* THE DISTRIBUTION OF COAL IN THE UNITED STATES, 366 *The Eastern province The Interior province The Gulf Coast province The Northern Great Plains and Rocky Mountain provinces The Pacific Coast province The geographical significance of coal distribution in the United States* COAL PRODUCTION IN THE UNITED STATES, 373 *United States foreign trade in coal Some problems of the American Coal Industry* COAL PRODUCTION IN EUROPE AND ASIA, 377 *Great Britain France, Belgium, and the Netherlands West and East Germany The European Coal and Steel Community Poland The Soviet Union China Japan India* COAL PRODUCTION IN OTHER CONTINENTS, 384 THE FUTURE OF COAL, 384 SELECTED REFERENCES, 385 SUGGESTED BRIEF READINGS, 385

22

PETROLEUM AND NATURAL GAS: HIGHLY MOBILE SOURCES OF POWER 387

IMPORTANCE OF PETROLEUM, 389 *Economic importance Industrial importance* PROPERTIES OF PETROLEUM, 390 FUNDAMENTAL ASPECTS OF PETROLEUM REFINING, 391 MODE OF OCCURRENCE, ORIGIN, AND RECOVERY OF PETROLEUM, 391 *Mode of occurrence Origin and recovery of petroleum Need for conservation of petroleum* GEOGRAPHIC DISTRIBUTION OF PETROLEUM PRODUCTION IN NORTH AMERICA, 395 *The Appalachian province The Northeast Indiana-Ohio province The Michigan province The Illinois-Southwest Indiana province The Mid-Continent province The Gulf Coast province The Central Plains province The Rocky Mountain province The California province The Canadian or Northern Plains province The Mexican Gulf Coast province Gas Fields of North America* COMMERCIAL DISTRIBUTION OF PETROLEUM PRODUCTS IN NORTH AMERICA, 404 *Transportation and storage of oil and gas* PETROLEUM IN OTHER AREAS OF THE WORLD, 408 *South America Western Europe Eastern Europe Near East Iran Iraq Arabia Southern and eastern Asia Africa Australia* CAPITAL INTERESTS, 416 THE OIL TRADE, 416 SUMMARY OF THE PETROLEUM OUTLOOK, 417 SELECTED GENERAL REFERENCES, 417 OTHER GENERAL REFERENCES, 418 OTHER SELECTED REFERENCES, 418 SUGGESTED BRIEF READINGS, 418

23

THE NUCLEAR ENERGY MINERALS: GEOGRAPHIC IMPLICATIONS OF THEIR USE 419

URANIUM, 419 *The uranium ores Nuclear energy World distribution of uranium Methods of production Uses of uranium Nuclear energy for the generation of electricity World trade Reserves* RADIUM, 427 PLUTONIUM, 428 THORIUM, 429 *Monazite* LITHIUM, 429 SUMMARY, 430 SELECTED REFERENCES, 430 SUGGESTED BRIEF READINGS, 430

24
THE IRON AND STEEL INDUSTRY: INDEX OF INDUSTRIALIZATION 431

THE IRON MINERALS, 431 *Hematite Magnetite Limonite Siderite* DISTRIBUTION OF IRON ORES IN ANGLO-AMERICA, 433 *The northeastern district The southeastern district The Lake Superior district The western district Iron-ore production and imports in the United States Canada* EVOLUTION OF IRON AND STEEL MANUFACTURING, 437 *Importance of scrap iron and scrap steel Localization of the iron and steel industry* THE IRON AND STEEL INDUSTRY OF ANGLO-AMERICA, 441 IRON AND STEEL CENTERS OF ANGLO-AMERICA, 442 *The United States Canada* IRON-ORE RESOURCES AND STEEL INDUSTRIES OF OTHER PARTS OF THE WORLD, 446 *Latin America Europe Great Britain The European Economic Community Other European producers Russia and adjacent countries Africa Asia (minus the Soviet Union) Australia* STEEL MANUFACTURE—INDEX OF INDUSTRIALIZATION, 455 SELECTED GENERAL REFERENCES, 455 OTHER SELECTED REFERENCES, 455 SUGGESTED BRIEF READINGS, 456

25
THE FERROALLOY METALS: STRATEGIC IMPORTANCE OF MINOR RESOURCES 457

ALLOY STEELS, 457 *Importance of the alloy metals* MANGANESE, 458 *Manganese ores in the United States Important foreign sources of manganese Summary* CHROMIUM, 460 *Chromite in the United States Supplies of chromite elsewhere* NICKEL, 463 *Occurrence of nickel Summary* MOLYBDENUM, 464 TUNGSTEN, 465 *Sources of tungsten ore Summary* VANADIUM, 467 SELECTED REFERENCES, 468

26
THE PRINCIPAL NONFERROUS METALS 469

COPPER, 469 *Copper ores Location of copper smelters and copper refineries versus that of mines The distribution of copper mining in the United States and Canada Copper production in Latin America Copper production in the Old World Other important copper-producing centers* TIN, 476 *Present uses of tin Mode of occurrence of tin Tin and the United States The world's sources of tin Other areas Outlook for the future* ALUMINUM, 479 *Uses of aluminum Mode of occurrence of aluminum Bauxite Conversion of bauxite into aluminum United States sources of bauxite Bauxite production outside the United States Future outlook* MAGNESIUM, 483 *Uses of magnesium Occurrence of magnesium Production of magnesium in the United States* LEAD AND ZINC, 485 *Uses of lead and zinc The ores of lead and zinc Geographic distribution of lead production The future of lead Geographic distribution of zinc production The future of zinc* SELECTED REFERENCES, 490 SUGGESTED BRIEF READINGS, 490

27

IMPORTANT ROCKS AND MINERALS OF DIRECT ECONOMIC USE 491

ROCKS AND MINERALS OF IMPORTANCE FOR CONSTRUCTION PURPOSES, 491 *Sand and gravel Clay Marble Granite Sandstone Slate Gypsum Asbestos Limestone* MINERALS OF IMPORTANCE TO THE CHEMICAL INDUSTRIES, 499 *Salt Sulfur* COMMERCIAL MINERAL FERTILIZERS, 504 *Nitrates Phosphates Potash* PRESENT AND FUTURE ROLE OF THE MINERALS AND ROCKS OF DIRECT ECONOMIC IMPORTANCE, 513 SELECTED REFERENCES, 514 SUGGESTED BRIEF READINGS, 514

28

NATURE AND GEOGRAPHIC DISTRIBUTION OF MAJOR MANUFACTURING INDUSTRIES 515

RELATIVE IMPORTANCE OF THE MAJOR GROUPS OF MANUFACTURES IN THE UNITED STATES, 516 THE CHEMICAL INDUSTRIES, 517 *Principal products and branches of the chemical industries* TEXTILES AND TEXTILE PRODUCTS, 522 *The cotton textile industry World distribution of cotton textile manufacturing The cotton textile industry in the United States The cotton textile industry in Europe and elsewhere Textiles of synthetic fibers Man-made fibers Worsted and woolen goods Knit goods Wearing-apparel manufactures* THE MANUFACTURE OF RUBBER PRODUCTS, 529 *Rubber in the United States* LEATHER AND LEATHER GOODS, 531 *The manufacture of leather Leather tanning in the United States* THE MACHINERY-MANUFACTURING INDUSTRIES, 533 *Metal working machinery Farm machinery and equipment Foreign trade in agricultural machinery* THE TRANSPORTATION EQUIPMENT INDUSTRIES, 537 *Railway equipment The motor vehicle industry The aircraft industries in the United States The boat- and shipbuilding industries* THE ELECTRICAL INDUSTRIES, 542 *Geographical distribution Exports of electrical products* THE ELECTRONICS INDUSTRIES, 543 SELECTED GENERAL REFERENCES, 545 OTHER SELECTED REFERENCES, 545 SUGGESTED BRIEF READINGS, 545

29

INDUSTRIAL REGIONS: THEIR DEVELOPMENT AND LOCATION 546

THE BASES OF WORLD INDUSTRIAL LOCATION, 547 *Factors favoring concentration of manufacturing Industrial concentration near coal fields Effects of other forms of power upon industrial concentration Industrial development near raw materials Industrial development in and near population agglomerations Industrial development in port cities Effect of industrialization upon the cultural landscape* THE PRINCIPAL INDUSTRIAL REGIONS OF THE WORLD, 552 *Industrial regions of northeastern United States. Industry in the South and West Industries in the Midwest The Far West Industrial regions of Europe Continental regions Other important areas of industrial development in the world* SELECTED REFERENCES, 557 SUGGESTED BRIEF READINGS, 558

30
GEOGRAPHIC ASPECTS OF TRANSPORTATION AND COMMERCE 559

OCEAN SHIPPING, 562 *Convergence of shipping on Western Europe* *The North Atlantic route* *The Mediterranean-Red Sea route* *Africa-Indian Ocean routes* *The eastern coast of North America* *The Pacific* LAND TRANSPORTATION, 570 *Railroad transport* *Motor transport* INLAND-WATER TRANSPORT, 577 *The Great Lakes* PIPELINES, 580 *Natural-gas lines* AIR TRANSPORT, 581 SELECTED REFERENCES, 582 SUGGESTED BRIEF READINGS, 582

31
THE GEOGRAPHIC BASIS OF ECONOMIC LIFE 583

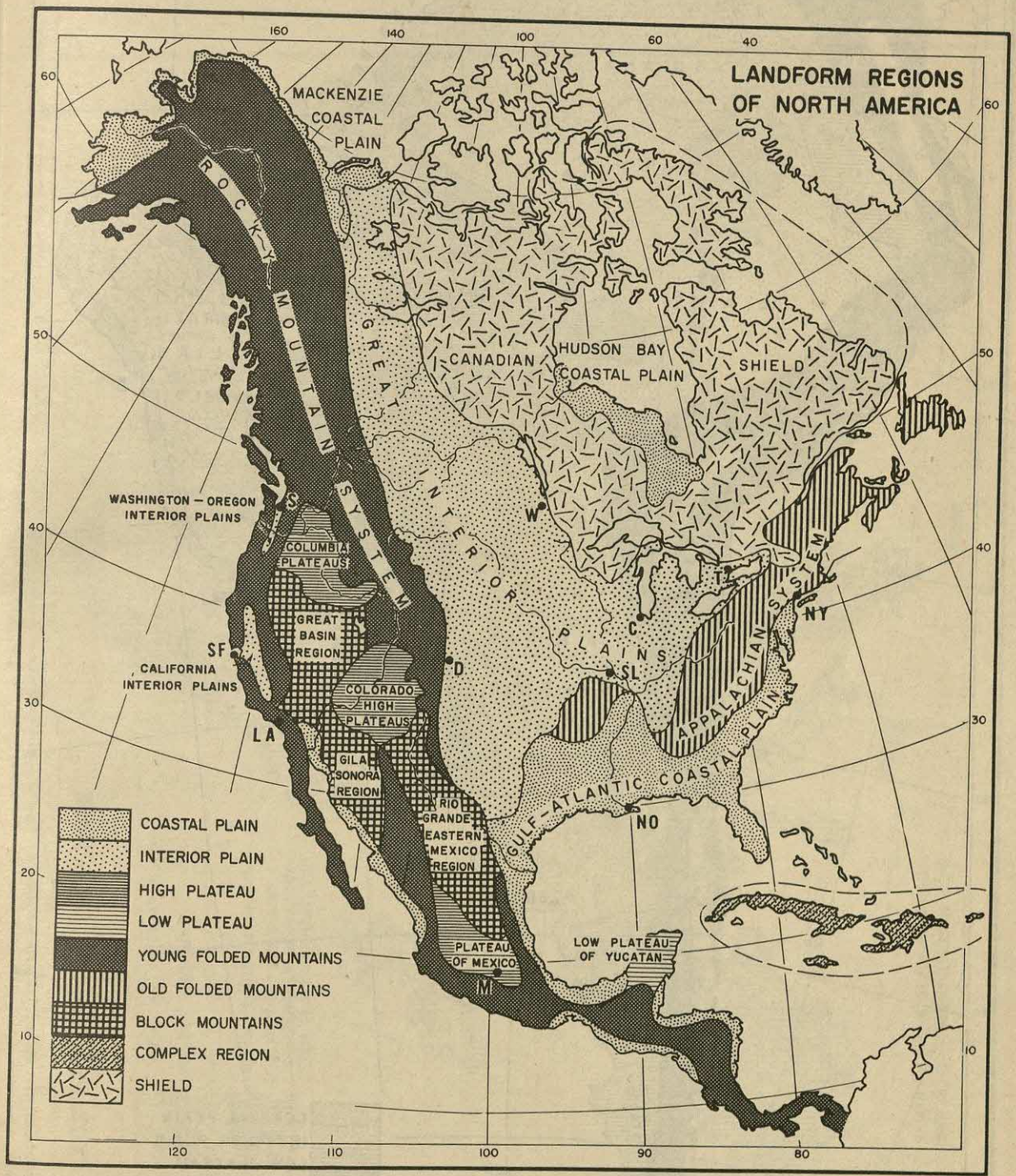
UNEVEN DISTRIBUTION OF NATURAL RESOURCES AND PEOPLE, 584 *Diversity and regional specialization of production* TRADE AS AN INDEX OF ADJUSTMENT TO INDUSTRIAL PROGRESS, 585 *The geographic basis of trade* THE RESPONSIBILITY OF BUSINESS TO THE PUBLIC, 587 PROBLEMS OF THE PRESENT AND FUTURE, 587

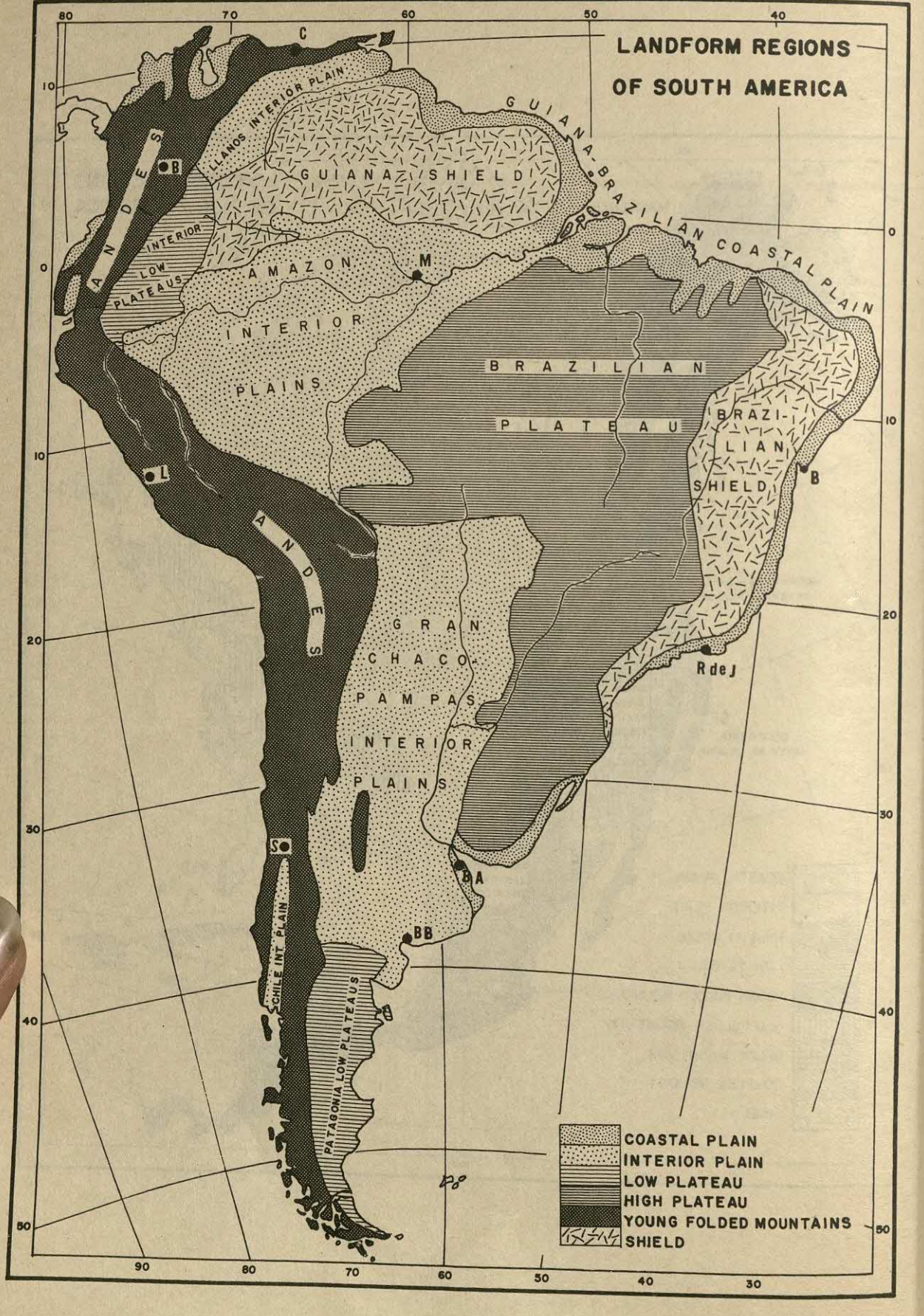
APPENDIX 589

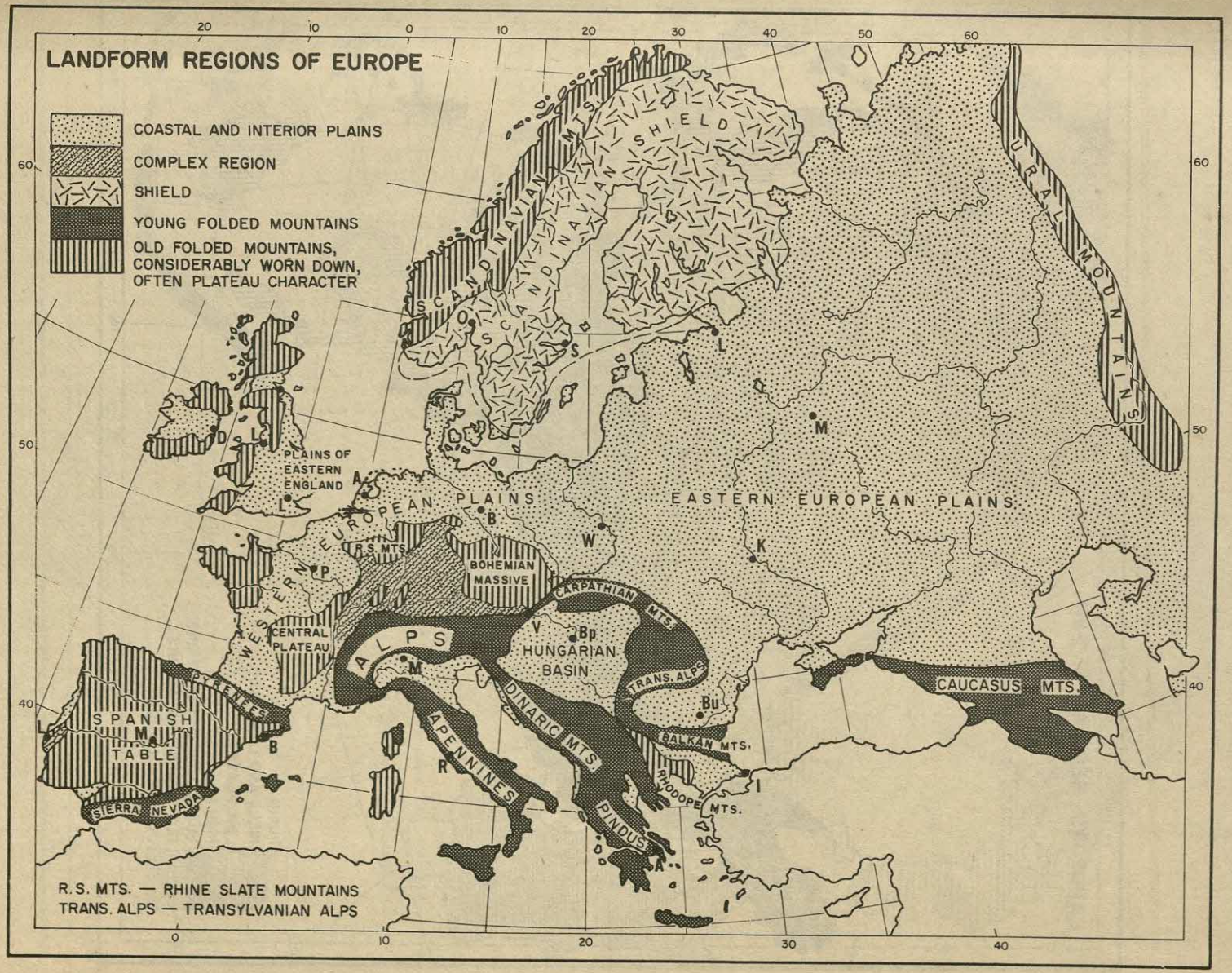
MAPS, 589 *Parallels and meridians* *The scale* MAJOR MAP PROJECTIONS, 592 *Mercator's projection* *The conic projection* *Polyconic projection* *The Mollweide homolographic projection* *Goode's interrupted homolographic projection —the homolosine* TIME ZONES, 595 *Reckoning of time* *Standard Time* *The International Date Line*

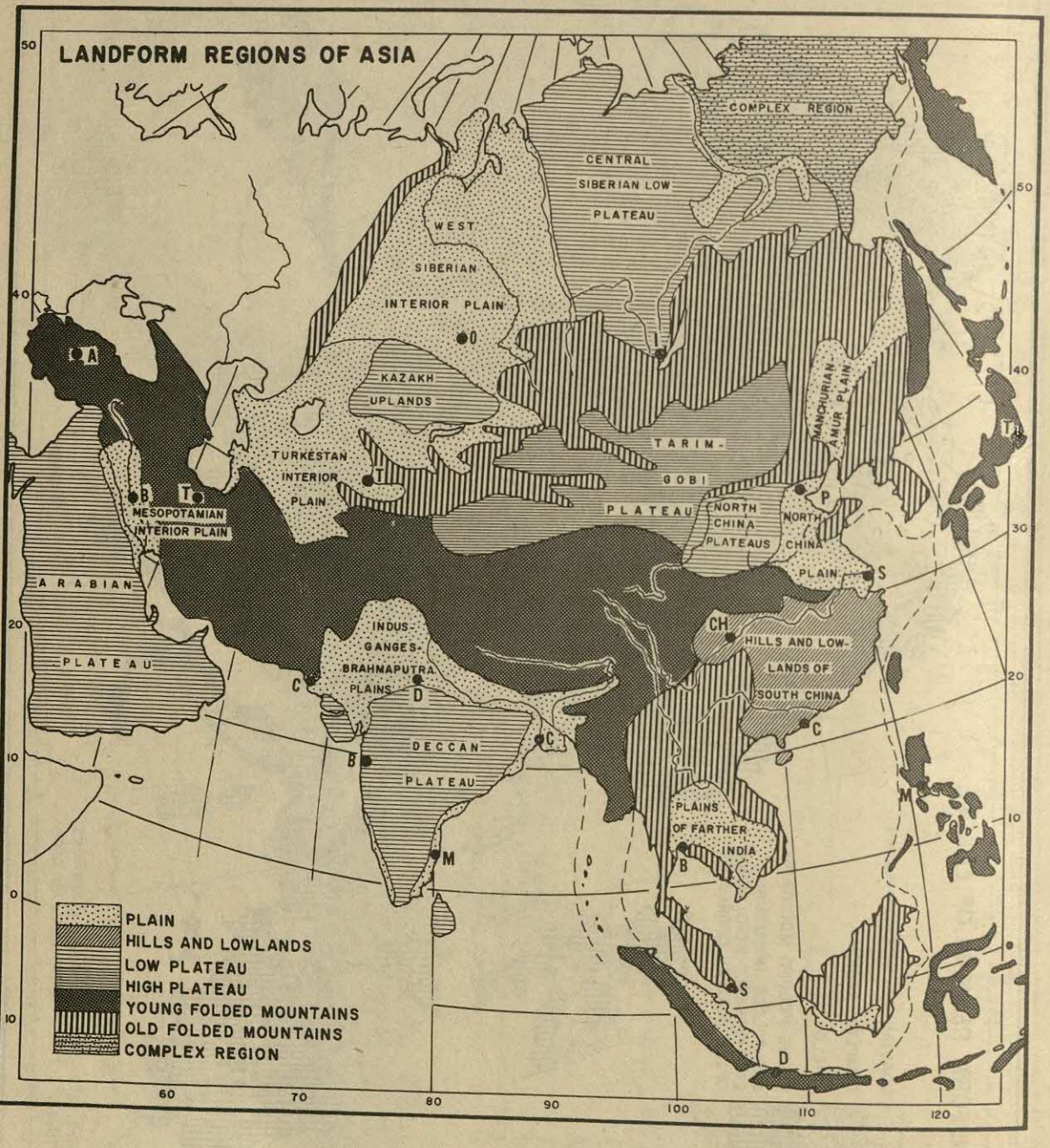
INDEX 599

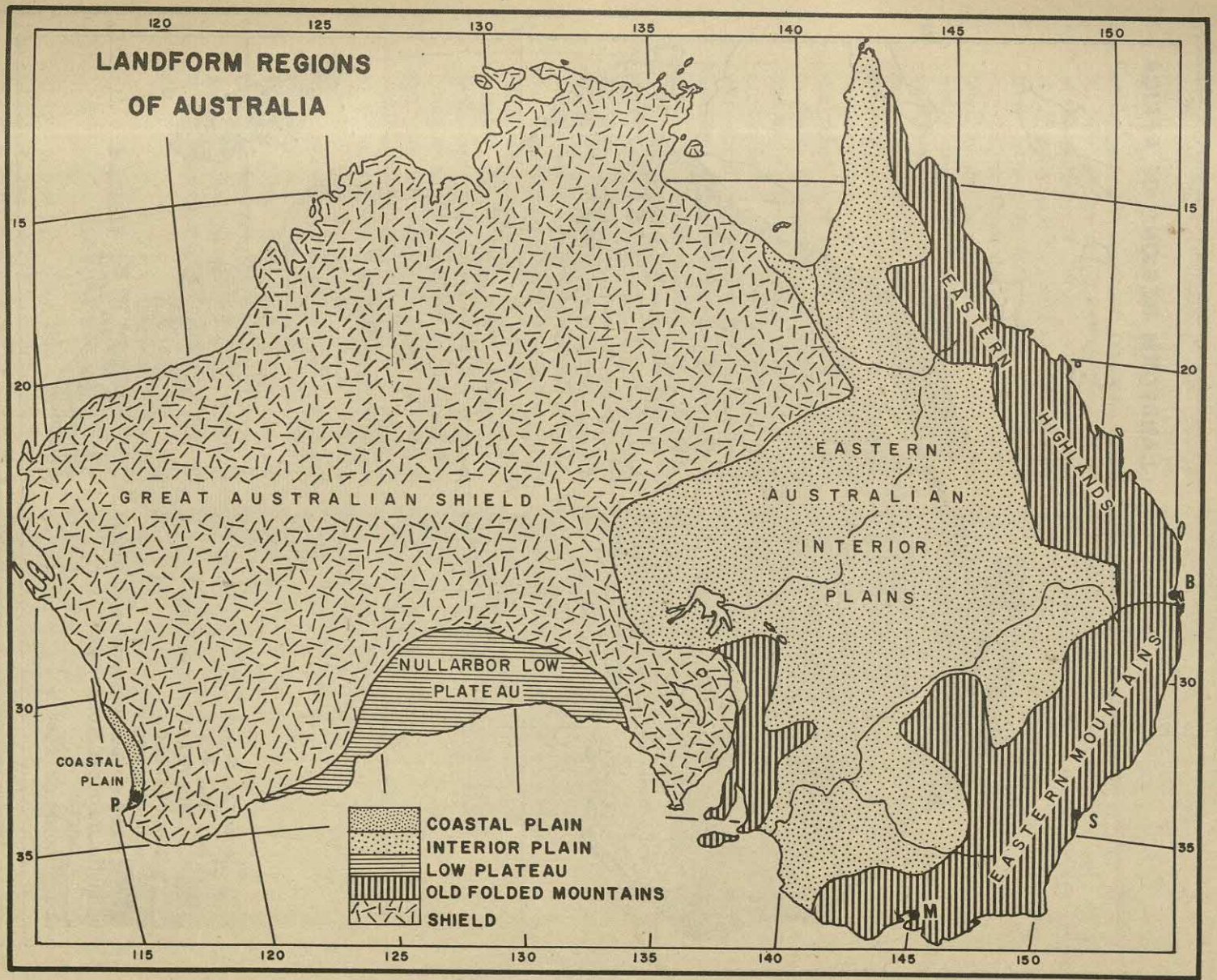
Fundamentals of
ECONOMIC GEOGRAPHY

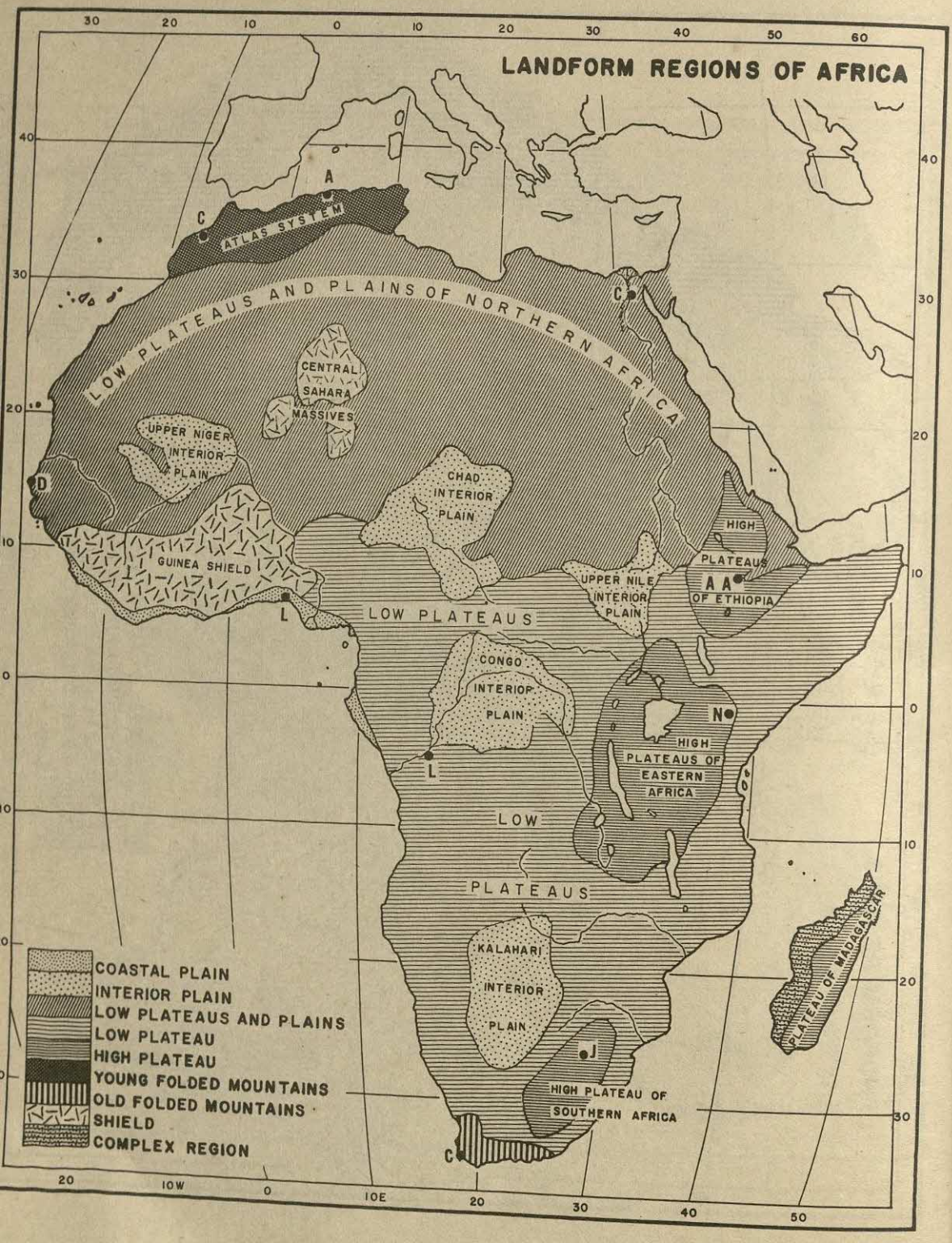

LANDFORM REGIONS OF NORTH AMERICA
MACKENZIE COASTAL PLAIN
ROCKY MOUNTAIN SYSTEM
GREAT INTERIOR PLAINS
CANADIAN COASTAL PLAIN
HUDSON BAY
SHIELD
APPALACHIAN SYSTEM
GULF-ATLANTIC COASTAL PLAIN
WASHINGTON – OREGON INTERIOR PLAINS
COLUMBIA PLATEAUS
GREAT BASIN REGION
CALIFORNIA INTERIOR PLAINS
COLORADO HIGH PLATEAUS
GILA SONORA REGION
RIO GRANDE EASTERN MEXICO REGION
PLATEAU OF MEXICO
LOW PLATEAU OF YUCATAN
SF
LA
D
W
C
SL
T
NY
NO
M
COASTAL PLAIN
INTERIOR PLAIN
HIGH PLATEAU
LOW PLATEAU
YOUNG FOLDED MOUNTAINS
OLD FOLDED MOUNTAINS
BLOCK MOUNTAINS
COMPLEX REGION
SHIELD
160
140
100
60
40
120
110
100
90
80
60
50
40
30
20
10


LANDFORM REGIONS
OF SOUTH AMERICA
ANDES
LLANOS INTERIOR PLAIN
GUIANA SHIELD
GUIANA-BRAZILIAN COASTAL PLAIN
INTERIOR LOW PLATEAUS
AMAZON INTERIOR PLAINS
BRAZILIAN PLATEAU
BRAZILIAN SHIELD
ANDES
GRAN CHACO-PAMPAS INTERIOR PLAINS
CHILE INT. PLAIN
PATAGONIA LOW PLATEAUS
C
B
M
L
S
BA
BB
Rdej
COASTAL PLAIN
INTERIOR PLAIN
LOW PLATEAU
HIGH PLATEAU
YOUNG FOLDED MOUNTAINS
SHIELD


LANDFORM REGIONS OF EUROPE
COASTAL AND INTERIOR PLAINS
COMPLEX REGION
SHIELD
YOUNG FOLDED MOUNTAINS
OLD FOLDED MOUNTAINS, CONSIDERABLY WORN DOWN, OFTEN PLATEAU CHARACTER
SCANDINAVIAN MTS.
SCANDINAVIAN SHIELD
URAL MOUNTAINS
PLAINS OF EASTERN ENGLAND
WESTERN EUROPEAN PLAINS
EASTERN EUROPEAN PLAINS
R.S. MTS.
BOHEMIAN MASSIVE
CARPATHIAN MTS.
CENTRAL PLATEAU
ALPS
HUNGARIAN BASIN
TRANS. ALPS
PYRENEES
SPANISH MESETA TABLE
SIERRA NEVADA
APENNINES
DINARIC MTS.
BALKAN MTS.
RHODOPE MTS.
PINDUS
CAUCASUS MTS.
R.S. MTS. — RHINE SLATE MOUNTAINS
TRANS. ALPS — TRANSYLVANIAN ALPS


LANDFORM REGIONS OF ASIA
COMPLEX REGION
CENTRAL SIBERIAN LOW PLATEAU
WEST SIBERIAN INTERIOR PLAIN
KAZAKH UPLANDS
TURKESTAN INTERIOR PLAIN
MESOPOTAMIAN INTERIOR PLAIN
ARABIAN PLATEAU
TARIM-GOBI PLATEAU
MANCHURIAN-AMUR PLAIN
NORTH CHINA PLATEAUS
NORTH CHINA PLAIN
INDUS-GANGES-BRAHMAPUTRA PLAINS
DECCAN PLATEAU
HILLS AND LOWLANDS OF SOUTH CHINA
PLAINS OF FARTHER INDIA
PLAIN
HILLS AND LOWLANDS
LOW PLATEAU
HIGH PLATEAU
YOUNG FOLDED MOUNTAINS
OLD FOLDED MOUNTAINS
COMPLEX REGION
50
40
30
20
10
0
10
60
70
80
90
100
110
120


LANDFORM REGIONS
OF AUSTRALIA
120
125
130
135
140
145
150
15
20
30
35
115
GREAT AUSTRALIAN SHIELD
EASTERN
AUSTRALIAN
INTERIOR
PLAINS
EASTERN
HIGHLANDS
NULLARBOR LOW
PLATEAU
COASTAL
PLAIN
P
B
S
M
EASTERN MOUNTAINS
COASTAL PLAIN
INTERIOR PLAIN
LOW PLATEAU
OLD FOLDED MOUNTAINS
SHIELD


LANDFORM REGIONS OF AFRICA
ATLAS SYSTEM
LOW PLATEAUS AND PLAINS OF NORTHERN AFRICA
CENTRAL SAHARA MASSIVES
UPPER NIGER INTERIOR PLAIN
CHAD INTERIOR PLAIN
GUINEA SHIELD
HIGH PLATEAUS OF ETHIOPIA
UPPER NILE INTERIOR PLAIN
LOW PLATEAUS
CONGO INTERIOR PLAIN
HIGH PLATEAUS OF EASTERN AFRICA
LOW PLATEAUS
KALAHARI INTERIOR PLAIN
PLATEAU OF MADAGASCAR
HIGH PLATEAU OF SOUTHERN AFRICA
COASTAL PLAIN
INTERIOR PLAIN
LOW PLATEAUS AND PLAINS
LOW PLATEAU
HIGH PLATEAU
YOUNG FOLDED MOUNTAINS
OLD FOLDED MOUNTAINS
SHIELD
COMPLEX REGION

1

Economic Activities and Their Physical Background

THE ECONOMIES of today, as they exist in the industrially more advanced parts of the world, are the result of long processes of evolution. Ancestral man probably began his slow upward climb as a simple gatherer of the products of Nature, collecting edible shellfish on mud flats and beaches, picking fruits from trees and bushes, and gathering roots and root stocks from other plants. Occasionally he would obtain meat from easily caught animals. Later, with better equipment, he probably began to fish and hunt systematically, thus substantially improving his material level of living, as in this manner not only did his food supply become somewhat more reliable, but he also had available the skins, bones, and sinews of the larger animals to use for clothing and a multitude of other purposes. These were undoubtedly the earliest forms of economic activities whereby man sought to assure himself of food and raiment.

For hundreds of thousands of years these activities probably yielded him little beyond the bare necessities for subsistence and for the continuation of the human race and left him no leisure to develop and enjoy any of the higher things of life. Beginning with these elemental activities of gathering and hunting, man through the ages gradually built our present-day complex economic structure with all of its varied and interlocking activities. Today a far-reaching division of labor and vastly more efficient methods of production have made it possible for man not only to obtain more than just a minimum of food, clothing, and shelter, but also to devote more time to the nonmaterial aspects of life. Economic activities of our time may be defined broadly as the various pursuits whereby man earns the means to satisfy his economic, social, and intellectual needs.

VARIETY OF ECONOMIC ACTIVITIES

At first one may think that any attempt to classify the manifold economic activities of today is likely to be futile. And yet, if a general perspective of the activities of the modern world is to be attained, some sys-

tematic plan must be worked out. Closer study will reveal that man's economic activities can be organized into a relatively small number of main groups or divisions, with each division having a "golden thread" of common interest running through it. It will also be found that each group operates within rather closely defined limits set partly by man and partly by Nature. One of the functions of geographic study is to discover, describe, and evaluate the relationships between economic activities and their physical background, that is, the natural conditions—or natural environment—under which they operate.

Hunting and fishing. Within a comparatively few centuries the areas where hunting and fishing for subsistence purposes are basic economic activities have been greatly reduced in extent. This change has come about largely as a result of the colonization of Australia and New Zealand by the white man, the settlement of the New World by the white man and the Negro, and the occupation of Africa by European powers. Subsistence hunting and fishing still survive here and there in South America, sections of Africa, certain parts of northern Australia, parts of the far north of Asia and North America, and in a few other places, but the importance of these two types of economic activities is decreasing steadily. It is to be expected that in the not too distant future hunting and fishing will be either sportive activities or economic activities of the commercial type.

Commercial hunting. Commercial hunting, and trapping, a form of hunting, are also economic activities that are decreasing in importance. The reasons for this are the gradual shrinkage in the amount of land suitable for the propagation of large numbers of wild animals and the frequently destructive methods used in commercial hunting.

As late as 1850-70 the Great Plains of the Middle West, from the Dakotas to Texas, provided pasture for a number of large herds of American bison. For generations these bison were hunted by the Indians for their supply of meat, fat, and skins. Until the arrival of the white man the Indians had to hunt on foot, and the number of bison which they could kill annually was therefore limited. During this period bison hunting remained a fairly well-balanced economic activity for subsistence purposes. When the Indians acquired the horse and flintlock guns from the white man they were able to make considerable inroads upon the bison population of the Plains. Still later the white man came with better guns to kill the bison for buffalo robes, and the hunt ceased to be an economic activity, becoming instead wholesale slaughter with no thought to future supply. A few bison still survive on reservations, and most of the lands of the Great Plains support crops or livestock.

Before the arrival of the white man other parts of North America were also a hunter's paradise. Besides offering millions of animals of the edible species, the continent teemed with fur-bearing types. Ever since the early fur traders penetrated deep into North America in pursuit of the prized pelts, trapping has been carried on in a rather ruthless fashion. Although it still offers a livelihood in parts of the wilds of northern Canada, in the United States it is becoming more and more an avocation. Commercial hunting in other parts of the world is also on the wane, for example, hunting elephants for ivory in Africa.

One of the results of the general decrease in the number of wild fur-bearing animals has been the raising, on a commercial basis, of such animals as silver foxes and chinchillas.

Commercial fishing. Fishing may be divided into inland fishing and marine fishing. The former connotes fishing in inland waters. The restricted area of such waters and the vigor with which fishing is usually carried on results in a rapid depletion of the fish population. This has brought about the necessity on the part of governments and private individuals of stocking such waters. In the United States millions of young fish are raised yearly in hatcheries for distribution into lakes and streams. Various European countries engage in this same procedure of artificial propagation, applying as much diligence and care as are needed to raise fine cattle or poultry. Much of the fish-

ing carried on in waters which are stocked artificially is a sportive, rather than an economic activity. Private fish culture in ponds is an important industry in some parts of China, Japan, and Java, where fish are produced in areas which otherwise would be economically useless. Much-needed food is provided in this manner.

Vast marine-fishing enterprises on a commercial scale are found in the middle and higher latitudes. For a further discussion of this type of economic activity and its physical background, see Chapter 18.

Agriculture. Agriculture was perhaps the first economic activity of man that led to a certain amount of sustained cooperation and some division of labor—in other words, to a higher degree of organization than was necessary for fishing and hunting. This is true regardless of whether early man was first primarily a tiller of the soil or a herder of beasts. The term agriculture in its broadest sense refers to all of man's activities related to the cultivation of the soil and to those activities that are directly dependent upon the soil, such as the raising of livestock. The production of vegetable food and meat made man less dependent upon the luck of the chase and therefore less subject to periods of famine following periods of feast. Nevertheless the influence of Nature upon agricultural activities was great and has remained so to this day. The types of crops that can be grown in an area depend first upon climate, soil, and the lay of the land, and there is little that man has ever been able to do against the vagaries of weather, such as unseasonal frosts, unexpected droughts, or periods of superabundant rainfall. Differences in the physical background have resulted in many types of agriculture throughout the world, and the number of types has been further increased by varying economic conditions.

Agricultural activities can be carried on for one of two main purposes: to supply local wants and needs or to furnish that which other people desire. Agriculture carried on for the first purpose is called *subsistence agriculture* and for the second, *commercial agriculture.*

SUBSISTENCE AGRICULTURE. The term subsistence agriculture is a relative one and varies in significance with time and place. Whereas in its earliest stages all agriculture was of this nature, today there is considerable variation because in many areas agricultural production is still partly for local sustenance and partly for sale on the market, the proceeds to be used for the purchase of other goods or services. Even the farmers of the Corn Belt of the United States still do some home butchering and home curing of pork and beef products for their own use, this aspect of their activities being distinctly one of subsistence agriculture. On the other hand, the largest portion of their crops of grain and forage is sold, either as such or in the form of fattened livestock or dairy products. This type of mixed-purpose agriculture is found in nearly all food-producing areas of the world. In some very densely populated areas, such as parts of China and India, farmers may consume directly all the grain which they produce because they cannot afford the luxury of feeding edible foodstuffs to animals to be converted into meat, and because production per farm is so low that there is usually only a small surplus to be exchanged for other goods. In such areas the farmer's opportunity to purchase the products of modern industry is very limited, and he himself must therefore make, by primitive and rather inefficient methods, many of the things which could be manufactured much more efficiently by modern machines.

Subsistence agriculture is thus characteristic of very densely populated areas, where total production of foodstuffs must be used directly in man's diet. It is also characteristic of areas where pioneer conditions prevail, where people are few, and where transportation facilities are wanting.

COMMERCIAL AGRICULTURE. The designation commercial agriculture bespeaks specialization in the production of one or a few agricultural products and the exchange of surpluses so produced for the many other needs of the producers. Agriculture in most progressive nations is now on this basis. (See Fig. 1.)

Modern transportation facilities by land and sea have greatly facilitated the possi-



Courtesy Government of the Netherlands

Fig. 1. Intensive commercial agriculture in the Netherlands. The raising of fruit and vegetables, such as grapes and tomatoes in hothouses. The latter can be identified by their roofs. Note how little land is not so used. Also note compact village and settlement along roads. This is part of the so-called Westland, southwest of The Hague.

bility of exchanging surpluses. The corn farmers of Iowa, the wheat producers of Alberta and the cotton growers of Mississippi may now exchange their products for coffee, cacao, bananas, spices, and other agricultural products of the lower latitudes or for products of city enterprises, such as factory goods, drugs, and medical services. For further details on agricultural systems and modes of agricultural production, see Chapter 7 and several succeeding chapters.

Forestry. For thousands upon thousands of years man kept himself warm by wood fires and cooked his food on them; he used leaves and branches as well as logs and lumber to build shelters, and he fashioned out of wood a multitude of implements. But while the tree has been his friend, man has been the enemy of the forest. In many parts of the world, such as India, China, Europe, and eastern North America, man has had to cut the forest to gain agricultural land, and he has left stands only where the soils were too poor or the slopes too steep. In some regions, as in southern Korea, man has taken all the lower land for crops, and the forests on the steep slopes above, with the exception of tiny patches in inaccessible places, have disappeared as a result of the eternal quest for fuel of the multitudinous population. Very little on these slopes seems to be given a chance to grow above the height of a man's knee.

Thus, during the last several thousand years the forest areas of the world have been greatly reduced in extent, and this process is still continuing. Even the tropical rain forest in parts of Africa is falling before the ax of the native at such a rate that in the countries of the Guinea coast, for example, it has become necessary to set aside forest reserves. The greatest issues confronting forestry in many parts of the world today are the need for adequate measures of conservation to preserve existing supplies for the future and the creation of new supplies by careful planning. Fre-

quently, in order to control the run-off of rain water and to prevent erosion of the slopes, forests must be preserved on lands that could be used for agricultural production. In Japan, for example, where population pressure on the land is tremendous, many areas must remain in forest because otherwise rivers would become uncontrolled, and valuable agricultural lands in the lower parts of the stream basins would become subject to periodic devastation.

It is sometimes erroneously assumed that forest products, particularly wood, are becoming less important. However, paper mills are continually making greater demands for wood pulp, and the rise of new and novel uses for wood is more than offsetting the declining use of lumber for building and other purposes.

Forestry may be roughly divided into logging and searching for forest products. Among the trees important for logging purposes are pine, fir, spruce, cedar, poplar, and beech (Fig. 2). Examples of forest products are gums, rosins, latex, cork, tannin, and wild nuts.

Forests are found in the more humid portions of the earth. As one proceeds toward the drier regions the forest first becomes more open, then the trees become smaller and stunted (good for fuel only), and finally one may arrive in areas where the climate is so dry that no forest can exist. In the northern parts of North America and Eurasia precipitation is comparatively low, but summers are cool, evaporation is small, and forests can flourish. However, still farther north the climate is too cold for trees.

It is to be expected that in the course of time forests will be limited largely to areas where crops or livestock cannot be effectively produced because soils are too poor, slopes are too steep, or the growing season is too short or to areas where a forest cover is essential for the control of stream flow. For a further discussion of forestry, see Chapters 9 and 16.

Mining and mineral exploitation. Mining, quarrying, and drilling are the more common methods of gaining access to mineral substances desired by man. Mining may be either by surface operations or by underground workings. Iron ore is so abundant at or near the earth's surface that in many places it is obtained by steam-shovel operations. Coal, although exposed in some

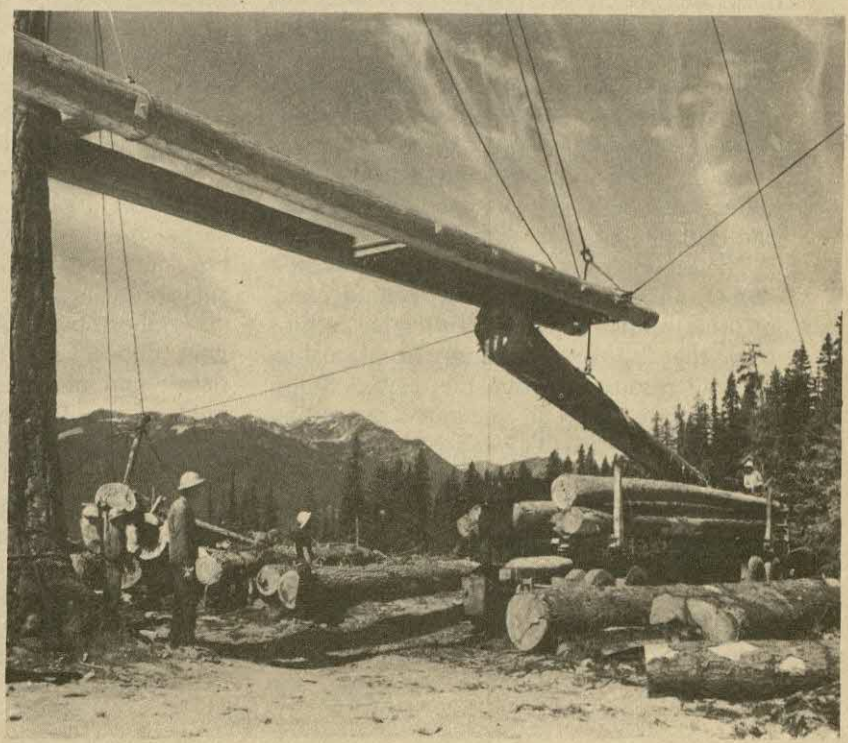
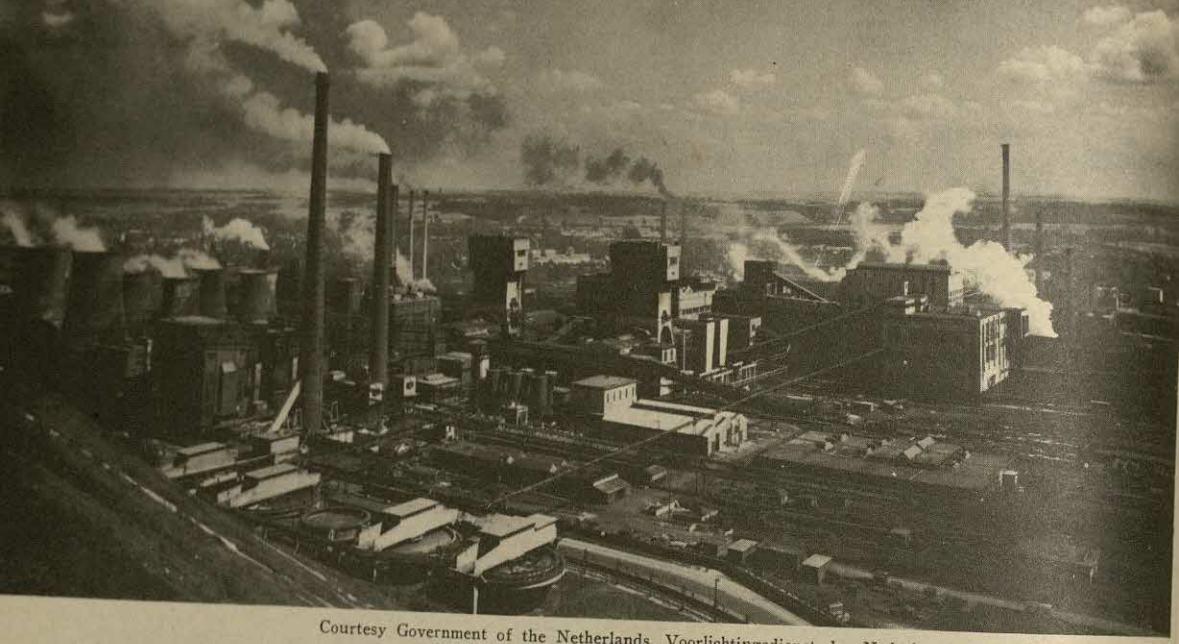


Fig. 2. Loading of Douglas fir logs onto logging truck in the Wenatchee National Forest, State of Washington. This forest is located on the east side of the Cascade Range.

Courtesy U.S. Forest Service



Courtesy Government of the Netherlands. Voorlichtingsdienst der Nederlandse Steenkolenmijnen

Fig. 3. A modern coal mine of the shaft type in the southern Netherlands. Note the two hoist towers or head frames in the center of the photograph. This is the Maurits mine, owned and operated by the Government of the Netherlands. In this mining area are three other government coal mines and seven privately operated mines.

Modern mining requires heavy investment in buildings and machinery above and below ground.

regions, is usually obtained via shafts and underground tunnels (Fig. 3). Metallic ores, such as copper, lead, and aluminum ores, are obtained by either or both of these methods.

The removal of stone, clay, sand, gravel, or other rock material from its natural position is termed *quarrying*. Another group of minerals, such as petroleum, natural gas, sulfur, and salt, are obtained by drilling and pumping.

The mining of coal and ores, the production of oil, and the quarrying of stone, clay, or other materials are all *extractive* industries, that is, they withdraw irreplaceable natural resources from the earth. Since many minerals occur in limited quantities at or near the earth's surface, local depletion is an inevitable consequence, which comes sooner for some, later for other mineral deposits.

Mineral resources, the raw materials upon which most of these extractive industries depend, are scattered widely over the earth in places or areas of limited extent rather than in broad zones, as is generally the case with agricultural resources. Exploitation of mineral resources therefore shows a pattern of irregular design which is characterized by small districts of intense activity and concentrated population separated by large areas of little mineral activity and comparatively sparse population.

Mineral exploitation, it may appear, is much less dependent upon the conditions of the physical environment than agriculture or forestry. In search of minerals of sufficient value, such as gold, man will go to very inhospitable places. Examples are the gold deposits of the western Australian desert and of eastern Siberia and the oil pools of the Arabian Desert. However, inhospitable conditions always result in higher costs of production. For example, to work the oil fields of the Arabian Desert, everything must be brought in, not only all the food and building materials, but even the water. For a further discussion of mining and mineral exploitation, see Chapter 19 and succeeding chapters.

Manufacturing and repair. Manufacturing refers both to enterprises in which raw or semifinished materials are converted into finished or nearly finished products and to tasks in which labor is applied to the construction or repair of things. Converting iron ore to pig iron is a form of manufacturing which uses natural raw material to make a semifinished product. This semifinished product, pig iron, then becomes a raw material for further processes of manufacture, such as the making of cast iron, malleable iron, and many types of steel. These products, in turn, are the raw materials used in industries which fashion the iron or steel into shapes needed for instruments, machinery and tools.

Manufacturing industries are generally classified as "heavy" or "light." In the heavy industries the ratio of skill and effort expended in proportion to the volume, weight, or value of the product is low. For instance, in the construction of a freight car the amount of skill and effort which is applied to a unit of weight or volume is much less than that which is applied in the construction of watches and clocks. Again, the sawing of lumber represents a task requiring less skill than the manufacture of typewriters and adding machines. The latter activities in these examples represent light manufacturing.

Generally speaking, the labor in heavy industries is of a less specialized, less technical nature than it is in light industries. This is an important factor in the mobility of these respective industries. Heavy manufacture, with its less-skilled labor requirements, can shift more readily to meet the exigencies of a changing industrial world. Light manufacture, on the other hand, tends to remain where the skilled workers reside, and the latter, strange as it may seem, are relatively immobile.

The use to which products are to be put falls into two categories, *consumer goods* and *capital goods,* the latter often being called *durable goods.* Processed foodstuffs, such as breakfast cereals, canned fruits and vegetables, and meat products varying from steaks to corned beef, are the most direct and well-known examples of the first category. Consumer goods also include textiles and wearing apparel because of the relatively short life of such goods when subjected to normal use. Capital goods include tools, machinery, and other equipment designed to promote production and income. Manufacturing concerns must always set aside a part of their income for the purchase of additional or newer capital goods.

The term durable goods is widely used in a less technical sense to include items of home equipment that are used principally to add to the comforts of living; typical examples would be musical instruments for home use, radios, refrigerators, tableware, and kitchenware.

Manufacturing is less closely related to the physical background than are the economic activities previously discussed. However, much manufacturing is carried on in or very close to areas of considerable population density rather than in sparsely populated regions far from major markets, and most of these more heavily populated areas originally developed because they were favorable to other economic activities, more directly dependent upon suitable conditions of the physical environment. Also, although the location of a particular industry or a particular plant may be the result of the initiative of one man or a small group of men, many types of industries, especially heavy, cannot be located too far from the source of raw materials or from places to which raw materials can be brought easily and inexpensively.

In the more industrially advanced regions of the world building and construction work of related kinds may be considered as being closely related to manufacturing since most of the items that are used in building, such as steel beams and bars, windows, doors, heating plants, and many other items, have been to some extent prefabricated. In less advanced areas the building materials may be fashioned on or near the spot, and they usually reflect rather faithfully the physical background. Sun-dried brick (adobe), for example, is still a common building material in areas of dry climate, where suitable clay is nearly

always locally available and where lumber is scarce and expensive. In areas where wood is plentiful, such as in the humid portions of the tropics, man may easily build a satisfactory hut with the trunks of smaller trees and the leaves of palms. In other areas large boulders or crudely fashioned pieces of stone may be major items in the construction of houses.

However, even in industrially advanced countries the major materials used may reflect the physical background. In countries such as the Netherlands, where there is comparatively little timber, frame houses are a rarity and brick is commonly used, while in northern Sweden and in parts of Finland and northern Russia wood construction predominates.

Culture, custom, and fashion may also, of course, have much to do with the aspect of dwelling houses, barns, and other structures. Nevertheless, throughout much of the world there is a relationship between on the one hand chief materials and type of construction and, on the other, the physical background, embracing both local resources and local or regional climatic conditions.

Manufacturing industries and industrial regions are touched upon in many of the following chapters and are discussed in more detail in Chapters 28 and 29.

Transportation and communication. Transportation and communication activities are the many enterprises that effect the conveyance of commercial goods and man and his messages. The terms should be interpreted broadly enough to include the many types of plants necessary for these operations.

The importance of transportation is such that most of our metropolitan areas would suffer serious shortages in less than a week if the importation of foodstuffs should cease. Rural areas would likewise be reduced to a subsistence level if transportation were discontinued.

The means of transportation and communication show such regional variations and have changed so much historically that a full discussion is not feasible here. Within historical times slaves furnished the motive power for crude vehicles and ships. Even now, as in parts of the Orient, human beings still pull or carry loads—coolies with rickshaws, or A-frames, and workers with their wheelbarrows are well-known examples. The use of animals for motive power marked an advance over the human method of transportation. For this purpose horses, donkeys, cattle, camels, dogs, llamas, elephants, and reindeer are commonly used (Fig. 4). Modern means of transportation utilize power obtained from mineral fuels or from falling water. By means of steam, electric, diesel, gasoline, or jet engines, voyages formerly requiring years and

Fig. 4. Mule train delivering mail in the upper reaches of the Lötschen Valley, Switzerland. Even in areas of modern transportation some of the older forms remain necessary adjuncts where rail and road cannot penetrate.

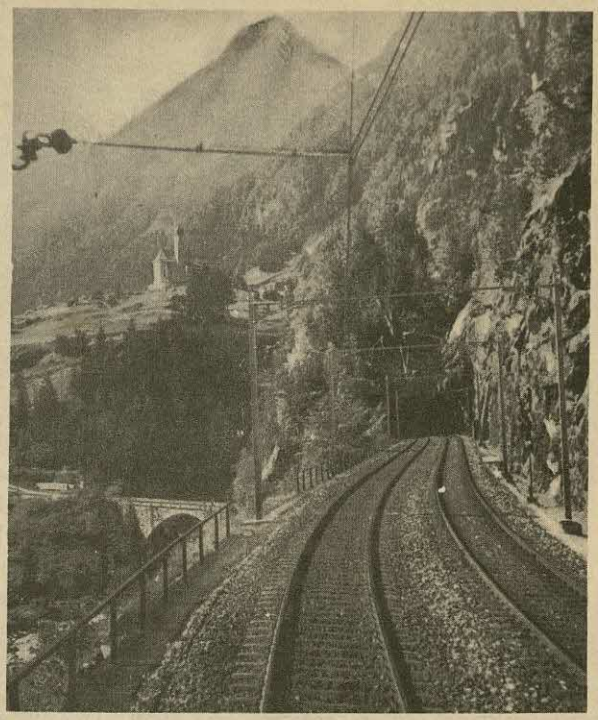
Courtesy Official Information Bureau of Switzerland. Photo by E. Gyger



months can now be completed in days and hours.

The more primitive methods of travel and transportation are greatly affected by physical conditions in the areas concerned. For example, in the parts of Africa where there are no hard-surfaced roads and few bridges, virtually all travel may cease during the rainy season. Even modern railroads and airlines are not independent of physical conditions. In the case of railroads in areas of considerable relief, steep grades can be overcome by appropriate engineering works, and it is possible to drill tunnels many miles long through the highest parts of mountains (Fig. 5). But man pays for overcoming these physical obstacles in the form of higher rates necessitated by the high cost of initial construction and the high cost of maintenance of mountain railroads. Airlines must always take the weather into account and sometimes must cease operation temporarily because of unfavorable atmospheric conditions; also, both local weather and local terrain must be considered in the location of airports.

Commerce. Commerce is closely related to transportation and communication. Where the latter exist, agencies must be instituted to bring about an orderly exchange of goods, that is, buying and selling, and



Courtesy Embassy of Switzerland

Fig. 5. Mountain ranges are no longer the serious barriers they used to be to transportation. Approach to the St. Gotthard tunnel near Wassen, Switzerland. Through a maze of spiral tunnels the electric railroad climbs to the main tunnel, located more than 2,000 feet higher up. However, such expensive engineering works necessarily result in higher rail transport rates. Also, in the same area, much more primitive forms of transportation remain a necessity.



Fig. 6. In isolated areas the small airplane has become very important as a means of transportation of goods and persons, particularly in the early phases of development work. The photo shows a pontoon-equipped plane used for flying in the Canadian north.

Courtesy National Film Board of Canada

the agencies which in part render possible or encourage such activities are included in the term commerce. Among the more common institutions of this kind are import and export houses, produce exchanges, shipping agencies, wholesale establishments, grain exchanges, banks, insurance companies, and retail businesses. Aspects of commerce will be considered throughout this book, and the geographic aspects of transportation and commerce are discussed in Chapter 30.

Professional, public, personal and domestic services. Positions in professional and public services require either special training or public trust. Scientists, engineers, educators, doctors, lawyers, religious workers, and administrators are the outstanding workers in these fields. Their professions are noted for the public leadership which they provide, and their trust is a serious one. It should be a matter of public concern to retain the highest possible standards for these professions. Under personal services are included occupations in homes, hotels, laundries, cleaning and dyeing institutions, and many other places. No classification of occupations would be complete without mention of the distaff side of life. A poet once said, "Man works from sun to sun, but women's work is never done." It is submitted herewith that the work of a woman in the home has been and is of such immense social significance that no writer need attempt to appraise its importance.

RELATIONSHIP BETWEEN ECONOMIC ACTIVITIES AND NATURAL OR PHYSICAL ENVIRONMENT

Man in an advanced society may not be as directly dependent upon certain local aspects of the natural or physical environment as man in a more primitive society, but the stake which he has in the knowledge and suitable use of his physical environment is even greater. Illustrations of this are the need of organized exploratory search for and efficient use of new petroleum fields, new deposits of potash, nickel, manganese, and many other minerals. In the realm of agriculture the factors of moisture, temperature, winds, sunshine, and length of growing season are of vital importance to production. Upon these factors depend the kinds of crops that can be grown, whether rye, wheat, rice or corn, for example, and the number of crops that can be produced on the same field in the course of a year. Landforms are likewise important because the use which is made of the land is directly affected by them. Floodplains, for example, may be suitable meadowland, but often are not safe for tillage agriculture; natural stream terraces generally make good crop land and are also highly suitable for irrigation purposes when sufficient water is available; lands of moderate slope may be suitable for tillage purposes only if artificial terraces are constructed to control erosion; highly dissected hilly lands with steep slopes may be suitable only for careful grazing or for forestry.

Nevertheless, the human factor in the development of economic activities must not be underestimated. Man may use existing resources constructively, or he may allow them to remain dormant, as he did for so many ages. Man himself is a potent geographical factor, as is evidenced by his clearing forests, replacing prairies with fields of grain, impounding waters to form lakes, tunneling through mountains, and by his changing the courses of streams. The extent to which man is able to alter the natural environment is shown in large cities, where many details of the original relief have often been altered by streets and structures which man has built.

RELATIONSHIP OF NATURAL LANDSCAPE TO CULTURAL LANDSCAPE

The natural environment in any given area is usually well reflected in the features of the *natural landscape*. This term refers to the land in its natural state, with its various kinds of surface forms, its streams and lakes, natural vegetation, and native fauna. Changes in the details of the landscape are brought about by man through such ac-



Fig. 7a. The natural landscape in an unirrigated section of the Columbia Basin in the state of Washington. The very low rainfall does not allow the growing of crops.



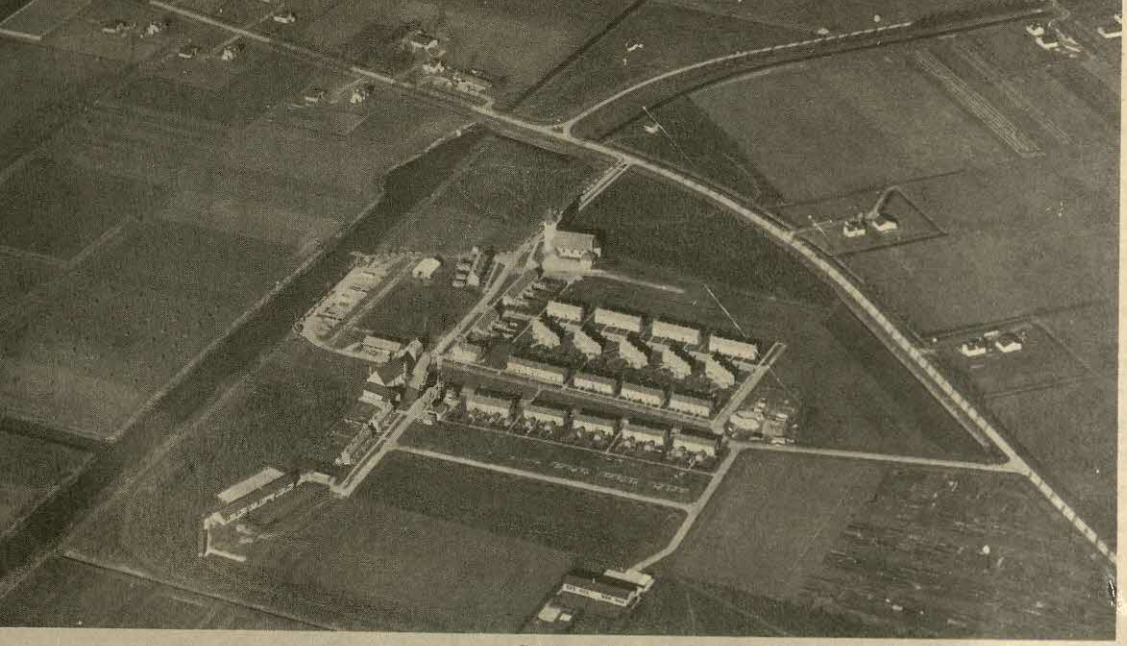
Fig. 7b. This photograph was taken from exactly the same spot as the photograph above. Note the mountains in the background. After irrigation large scale production of peas became possible. This now is becoming a cultural landscape.

Courtesy U.S. Bureau of Reclamation

tivities as plowing up the sod, cutting down the forests, planting various crops, straightening or deepening stream channels, constructing irrigation projects, preparing grades for roads and railroads, and constructing houses, barns, factories, villages, towns, and cities. In these and other ways the natural landscape is rendered more adaptable for man's use, and a *cultural landscape* is thus created. (See Figs. 7-a and -b.)

A cultural landscape in its fullest sense would imply a complete fade-out of the features of the original natural landscape and their replacement by man-made features. There are relatively few areas which may be considered "pure" cultural landscapes. Perhaps some of the areas reclaimed from the bottom of the Zuiderzee in the Netherlands come closest to being such (Fig. 8). Areas of pure natural landscape, that is, regions where man has caused no changes, still exist in different parts of the world, but their extent is being reduced every year. The only really large area of natural landscape is Antarctica. Even in the northern wildernesses of Canada and Siberia man is beginning to leave his imprints.

Usually a landscape is a combination of both features, the cultural having been superimposed upon the natural in varying proportions. In grazing areas, such as those in southwestern United States, or in parts of the Great Plains, the principal cultural features are fences, widely spaced houses, and trails and roads. In farming areas man's imprint on the natural landscape is more distinct—grass and forest are replaced by cultivated crops; farmsteads are built close



Courtesy Government of the Netherlands; Foto KLM Aerocarto N.V.

Fig. 8. A completely cultural landscape. The village of Luttelgeest in the Noordoostpolder. This is one of the sections of the former Zuiderzee that has been reclaimed. All that is visible in the photograph has been created by man from the former sea bottom.

together and are connected by telephone and, perhaps, power lines; and roads are constructed to nearby towns. Despite all these changes in detail, the general topography remains virtually unchanged in respect to flatlands, hills, and valleys. In the cities, however, man's structural activities are generally dominant—hills are reduced, grades are lessened, and much of the original landscape is concealed by streets and buildings.

In order to understand and appreciate the natural landscape, as well as its various modifications into a cultural landscape, it is well to review the major aspects of the former. It is possible to better comprehend the geographical individuality of an area and to better evaluate the changes, for better or worse, which man has made if the major aspects of the region concerned are observed, described, and explained. Wherever man modifies the natural landscape he is apt to upset a number of delicate natural balances. In order to prevent irreparable damage it is necessary to study carefully the manifold reciprocal relationships between man and the region in which he has made his home.

The principal aspects of the natural landscape may be listed as: (1) location, (2) landforms, (3) water bodies, (4) climate, (5) land content, or soils and mineral deposits, (6) native vegetation, and (7) native animal life.

Location. Two kinds of location may be recognized: *absolute location* and *relative location.* The absolute location is given by the latitude and longitude of a place (see Appendix). This in itself may give valuable indications as to the nature of the area concerned: whether it is an island or part of one of the continents, and whether it is located in the warmer parts of the world, in the middle latitudes, or in the cold polar regions. Relative location refers to location of a place or a region with reference to other items of the landscape, be they natural or cultural. Is it near the shores of one of the oceans, where, for example, the climate may be modified by winds from the water? Is it in or near high mountains? Is it on an important navigable river? Is it near one or several railroads? A good statement of relative location may convey much information regarding the nature of the area or place concerned as well as its economic potentialities.

Relative location is often a major factor

in the growth possibilities of a city or in the success of a business. For example, it is clearly recognized that small towns located at a certain distance from a large city rarely grow into important trading centers because they are overshadowed (Fig. 9).

Landforms. In the characterization of an area the forms of the land are of prime importance. Not only are these the features of the landscape which one usually notices at first glance, but the various types of landforms may give a different character to both natural and cultural landscapes. The student should be acquainted not only with the nature of such major landforms as plains, hilly lands, plateaus, and mountains, but also with that of the forms of lesser magnitude, such as ranges, ridges, cuestas, moraines, dunes, river terraces, floodplains, and many others. Relief and degree of dissection, as well as altitude, are other important items to be considered.

Water bodies. That bodies of water are important landscape features is evident to all. What small boy in a country district has not felt the spell of the swimming hole or experienced the thrill of catching minnows which later, as the stories are retold, become magnificent rainbow trout or huge channel catfish?

The indirect influence of water bodies pervades all land areas of the earth. The water that falls as rain must originally have come from the sea, whence it rose as water vapor. Large water bodies modify temperatures of the lower air over sea and land. They do so to the greatest measure in coastal areas, but the largest water bodies, the oceans, may to a lesser degree make their influence felt far inland. In addition

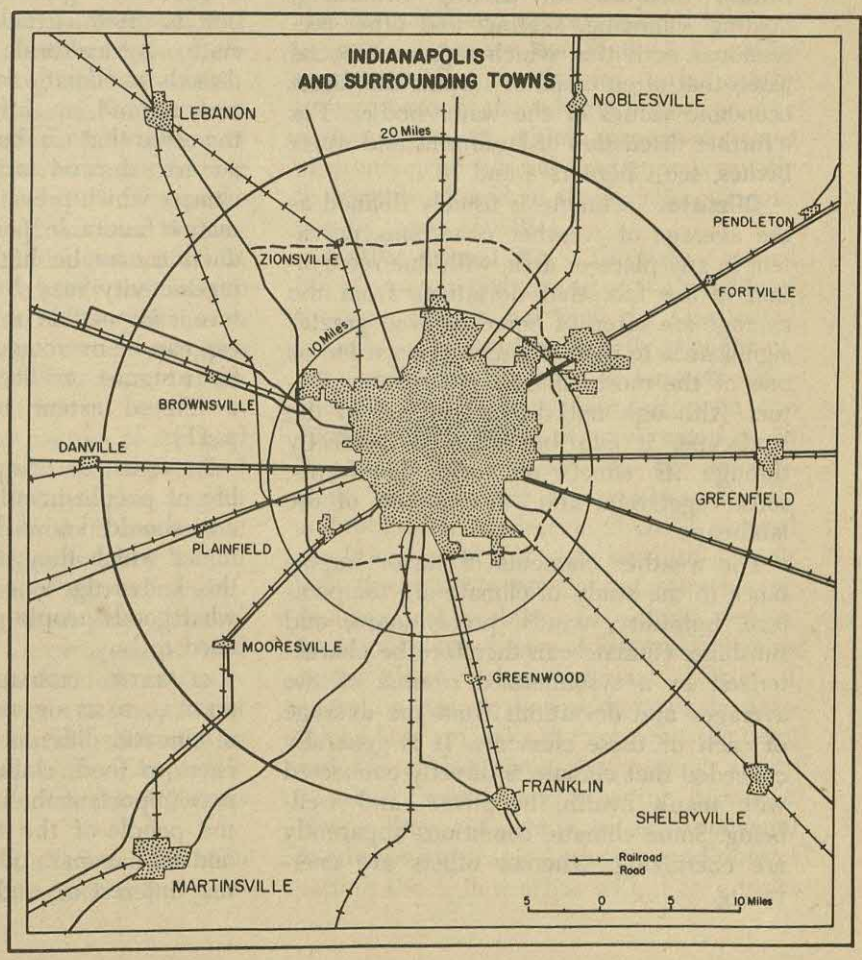


Fig. 9. Indianapolis and surrounding towns. Railroads and main highways all center upon Indianapolis. The influence of the city has precluded the growth of towns within a considerable radius, except those of a suburban residential character.

to the effects that large water bodies have upon weather and climate, are the important geographic relationships that they have with transportation and industry. Ocean-borne commerce makes the whole world kin, enabling us to sell our goods in all parts of the world and, in turn, to enjoy the products of distant lands in our own scheme of living.

The influence of water bodies is not limited to that of the great seas and oceans. The small lakes which in many areas are peppered over the land and the networks of streams which cover the land in all but the very driest regions are important items in the landscape and directly affect the man who lives near them. Because they may provide water supplies, means of drainage, power, transportation routes, they are of economic significance to every community. Furthermore, the lakes, ponds, and streams furnish facilities for fishing, swimming, boating, canoeing, skating, and other recreational activities which represent social assets that often equal or surpass the direct economic values of the water bodies. For a further discussion of landforms and water bodies, see Chapters 4 and 18.

Climate. Climate is usually defined as the average of weather conditions prevalent in any place or area, with due recognition of the fact that deviations from the average are often of equal or even greater significance to man. Climate is regarded as one of the most effective geographic factors. Although not directly visible in the landscape, it can be observed indirectly through its effects on rocks, landforms, soils, vegetation, and other aspects of the landscape.

The weather elements of major importance in the study of climate are temperature, humidity, winds, precipitation, and sunshine. Climate can therefore be characterized by a systematized résumé of the averages and deviations from the average of each of these elements. It is generally conceded that climate is directly connected with man's health, happiness, and well-being. Some climatic conditions apparently are energizing, whereas others are enervating.

Climate not only affects the health of man but also his mode of life. The intimate relationships between climate and food, shelter, and clothing are generally recognized, and illustrations of these relationships can be found everywhere. In cold lands the houses generally are sturdily built with thick walls, solid foundations, and elaborate heating systems, whereas in warm lands the houses do not ordinarily have such features. The dwellers of cold lands clothe themselves in hides, furs, and woolens, while those of warm lands wear clothes which are light and airy. People in the arctic regions consume great quantities of fats and do so with evident relish, whereas those in the tropics live on much lighter diets, placing greater dependence upon fruits and vegetables.

Many of man's activities are also influenced by climate. Where a certain kind of domesticated plant or animal may thrive best is often virtually determined by climate. Agricultural production responds directly to climatic factors such as temperature, rainfall, sunshine, and wind, and thus the crops that can be grown in any particular area depend largely upon the type of climate which prevails there. Where the climate is favorable, potential agricultural production may be high; where unfavorable, productivity may be so low that agriculture is impossible unless the climatic handicap can be overcome by artificial means as, for instance, aridity may be overcome to a limited extent by irrigation (Fig. 7, p. 11).

In order to comprehend the economic life of people in other parts of the world, one should know the climatic conditions under which they make their living. With this knowledge one can better understand what goods people produce and what they need to buy.

CLIMATIC DISSIMILARITY AS A FUNDAMENTAL BASIS OF TRADE. The significance of climatic differences goes beyond differences in food, clothing, and shelter, however important these may be. The fact that the people of the tropical lowlands grow and eat bananas and coconuts in abundance may interest us, and at times we may even

feel envious because of their good fortune in this regard. The real economic significance of these facts, however, is that through surplus production and efficient transportation bananas and coconuts have become available in regions where they cannot be produced, and thus they have become commodities of world commerce. The same holds true for a great number of other agricultural products. Industry draws upon areas both near and far for raw materials of a vegetable nature which cannot be produced in the areas of manufacture because of unsuitable climatic conditions. Differences in climatic conditions are thus one of the most fundamental bases of trade, both domestic and international. For example, the farmers of Iowa produce a surplus of meat and other animal products, the sale of which enables them to purchase manufactured goods from the East and citrus fruits from Florida and California. Canada produces a surplus of wheat, lumber, and furs and imports products of more southern climates. The people of tropical Latin America may buy the products of the northern climates if they can sell their surpluses of bananas, coffee, etc. Thus, to a considerable extent, the currents of trade flow in response to climatic differences. If we wish to comprehend the fundamental bases of trade, we should not neglect to study the climatic factors involved. For a further discussion of climatic factors and climatic types, see Chapters 5, 6, and 7 as well as several of the following chapters.

Land content. The content of the land should be thought of as consisting of soil material and mineral deposits. This content is responsible for differences in the natural landscape; for example, soils often have a bearing upon the type of natural vegetation which can grow in an area. Mineral content is responsible for certain aspects of the landscape as well as for different types of mining and quarrying in many parts of the world. Soils are further discussed in following chapters, especially Chapter 7. Mineral resources are discussed in Chapters 19 to 27.

Native vegetation. Native vegetation refers to the natural plant growth that mantles the earth's surface. In some places the vegetation cover is quite simple, as in parts of the southern pine forests, where large areas carry only a few species of trees. In other places it is exceedingly complex, as in the low-latitude rain forests. Inasmuch as most plants are practically immobile, that is, they cannot move about, they must depend entirely upon their immediate environment. Where a number of different kinds of plants are present, those species dominate which are best adapted to the growth and maintenance factors of that locality. These factors are the soil and the climatic elements.

Crop plants cultivated by man are not included under the term native vegetation. Wherever man breaks the sod, cuts the forest, or stirs the soil and cultivates crops, he creates an artificial, a cultural landscape. Thus, areas devoted to tree crops such as rubber, cacao, coconuts, olives, or apples and fields planted to corn, wheat, tobacco, or sugar cane are not clothed in native vegetation, but are farmed areas constituting phases of the cultural landscape. The native vegetation which survives in areas of pronounced cultural landscape is usually thoroughly altered in its floristic composition by man's activities.

Native animal life. The native animal life of a region includes all of the wildlife of the area, that is, not only the four-footed animals such as are ordinarily thought of, but also fish, birds, snakes, and insects. Since animals subsist upon plants or upon one another, the wildlife of any region is, in large measure, a response to the environment. Yet animal life is not quite so directly and intimately a reflection of environmental conditions as is plant life because animals have the power to move about, some having developed this ability to a high degree. Birds and some species of fish rank foremost among those with exceptional abilities of migration. Among the land animals the fleet-footed kinds, such as the antelope, the deer, and the rabbit, show the greatest ability in moving swiftly and covering distances. Hence they can overcome environmental handicaps by escaping adverse conditions at various times. In contrast with these species

are those whose ability to roam is limited to narrow confines. They can progress, but slowly and only within restricted conditions of environment. Examples are the hippopotamus, characteristic of some of the rivers and adjacent marsh areas of Africa, and the alligators and crocodiles, which, although fully equipped with powers of locomotion, cannot travel a great distance from their water habitat. Many of the insects have little capacity for flight.

The native animal life may be classified with respect to its relationship to man. Some animals are used for food, whereas others are valuable only for the materials that they furnish for clothing or shelter purposes. Still others have almost no value to man, but are a negative factor in that their presence is mostly harmful.

In recent centuries the number of large wild animals has decreased greatly, partly as a result of the expansion of agricultural land, partly because of hunting with modern firearms. This is true even in parts of Africa. It is an unexpected sight to watch Negro mothers wheel their babies to the zoo in Bamako, on the Upper Niger river, there to admire giraffes, elephants, lions, and hippos living contentedly and safe from the rifles of the hunting safaris that have decimated so much of African animal life.

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2

Distribution of Mankind

its significance and its dynamic aspects

In any given area the nature and extent of man's economic activities depend to a certain degree upon his numbers. This also applies to the rate at which and the extent to which man changes the natural landscape into a cultural landscape. His numbers are important, too, in relation to the availability of the things that he needs from nature—basic resources, such as water, land for grazing or tillage, and minerals for manufacturing purposes. Finally, as man is the originator of all economic activities, his geographical distribution over the earth gives us a general idea of the intensity of economic activities and of exchange or trade patterns resulting from the grand pattern of economic activity.

World population. Even today, when most countries at least from time to time take a census of their population, we do not know the exact total of the world's population in any given year. There is always a margin of error in census data. Although this margin is small in countries with advanced census techniques, such as the United States or countries of Europe, it may be quite large in countries where many people cannot read or write and where communication is still difficult. The information which we have pertaining to the population of the world of several centuries ago, before the time of modern censuses, has, of course, a much greater inherent margin of error. Nevertheless, it is fairly safe to say that about A.D. 1600 the population of the world was probably around 500 million. This number was the result of a very slow increase in population over many thousands of years. Because of the ravages resulting from epidemic diseases, such as the pest, slow, debilitating diseases, and the prevailing high rate of infant mortality, population growth must have often come close to a standstill. Also, in many parts of the world almost constant local or regional warfare was the rule rather than the exception.

By 1900, within a span of only three centuries, world population had tripled to a total of about 1,500 million. At present it is over 3,000 million, which means that the figure has doubled within a span of about two thirds of a century.

This phenomenal increase in world population has affected the entire range of man's economic activities as well as the rate at which he is utilizing his basic resources. A result of this increase has been the comparatively recent spread of modern economic activities into certain areas, such as parts of the tropics and parts of the higher latitudes, where for thousands of years there had been few or almost no people and where economic activities had been of the simplest type, such as gathering, hunting, and perhaps a little agriculture on a very primitive level.

Distribution of world population. One of the most striking facts about the distribution of mankind over the earth is its great unevenness, a fact which pertains to the present as well as the past. For hundreds of years the areas with the highest concentration of population were: (1) the Near East, especially the area stretching from the lower Nile valley and delta of Egypt via the lands back of the eastern coast of the Mediterranean to the lowland of Mesopotamia, with extensions into western Iran and eastern Asia Minor; (2) the remaining region around the Mediterranean Sea; (3) the Indian peninsula; and (4) the lowlands of eastern China.

Elsewhere in the world, with the exception of a few isolated spots, population was very sparse indeed. The New World had very low population densities, except for three comparatively small favored areas, the southern portion of the Plateau of Mexico, the Yucatan peninsula, and parts of the Andean highlands in South America, as it is estimated that at the time of the Spanish discovery all of North America north of the Rio Grande river had no more than one and a half million inhabitants.

During the Middle Ages population continued to increase in the regions mentioned above, but another area of concentration began to develop in Europe. This area extended from the Mediterranean Sea as far north as southern Scandinavia.

The exploration of the world by European navigators, which began a number of decades before Columbus landed in what are now the Bahama Islands, brought about major changes in world distribution of population: the settlement of Spanish and Portuguese in Latin America; that of Anglo-Saxons and others farther north in the New World; the forced settlement of Negroes in many of the warmer parts of the Western Hemisphere, from Brazil to southern United States; the settlement of Dutch and others in southern Africa; and that of Anglo-Saxons and others in Australia and New Zealand. During approximately the same period that these changes took place, the Russian people spread toward the Black Sea and the Urals, east of the Urals across Siberia, and as far east as the Sea of Okhotsk in eastern Asia.

These constituted the greatest changes in population distribution which the world had experienced since the end of the last glaciation, approximately 10,000 years ago.

Enormous areas of fertile and comparatively empty lands were thus brought into much more intensive use, contributing greatly to the total productivity of man's economic activities. Today there are still a number of comparatively empty areas left. Some of these hold little promise for the future, but others could undoubtedly sustain a larger population than they now do. Included among the latter are extensive areas of tropical lands in South America and Africa and smaller ones in the Australasian archipelago. However, these lands are of an entirely different nature than the great plains of North America, Russia, or Australia. Denser settlement of these tropical lands poses much more difficult problems, and these problems cannot possibly be solved by individual initiative alone. Far greater capital resources will be needed, as well as careful preparatory work by many types of scientists.

PRESENT DISTRIBUTION OF POPULATION

Europe is the most densely settled continent, and Australia is the least, as the following list shows:

Approximate Number of People per Square Mile	
World	57
Europe, without USSR	220
Asia, without USSR	150
USSR	25
Middle America	52
North America	28
Africa	20
South America	20
Australia	5

While such broad differences are interesting, they mask the facts of actual distribution because each continent has different proportions of densely settled and sparsely settled land. Although North America as a whole has about 28 people per square mile, the United States (so-called conterminous United States, i.e., without Alaska and Hawaii) has 60 people per square mile, and, within the United States, Rhode Island has over 800, whereas Nevada has less than 3. Figure 10, page 20, shows world distribution of population by different degrees of density per square mile, with no regard given to international boundaries.

The densely settled lands. This map shows that four parts of the world stand out above all others in density of settlement: (1) eastern Asia, (2) southern Asia, (3) central and northwestern Europe, and (4) northeastern United States, although to a lesser extent. Eastern and southern Asia have by far the largest population—nearly half the inhabitants of the world. The people are especially concentrated in the great river valleys and coastal plains of India and China, on the various islands of Japan, and on Java. Average density figures for China as a whole (about 175 people per square mile) and India (370 people per square mile) obscure the fact that in the best farming areas the population density may far exceed 1,000 people per square mile. The average for China is particularly far from representative because of the presence of extensive mountain and desert areas. Japan has well over 600 people per square mile, and Java, with still less wasteland, has over 1,000. In northwestern and central Europe the Netherlands leads the list with about 900 people per square mile, followed by Belgium with close to 800, and England and Wales with about 770. Only slightly less crowded are West Germany (between 500 and 600), Italy (between 400 and 500), and Switzerland (between 300 and 400). Denmark, Poland, Czechoslovakia, Austria, and Hungary, belong to the 200-300 category.

In northeastern United States the area between Baltimore and Boston campares with the areas of dense population of northwestern Europe: Rhode Island, New Jersey, and Massachusetts have densities of well over 600 people per square mile, and Connecticut of over 500. Most of the industrialized districts in the area between New York and Chicago have similar densities, although the inclusion of sparsely settled areas in each of the states concerned results in lower state ratios.

In addition to the four major areas of dense population mentioned above, there are many smaller areas where equally or more crowded conditions obtain. These conditions are found particularly on small islands, such as Bermuda (about 2,100 people per square mile), Barbados (1,400), and Puerto Rico (close to 700); in many large cities and their environs; and in intensively cultivated agricultural oases, such as the lower Nile valley.

The thinly settled lands. A study of the map of world population (p. 20) shows that the most thinly settled areas, that is, those with less than two people per square mile, cover about half the land area of the world. Comparatively empty areas appear in the northern portions of both hemispheres, in interior South America, in northern Africa, central Asia, Australia, and, of course, in Antarctica.

Causes of differences in population density. What causes these great differences in density? There is no single factor, nor any single group of factors, such as historical or geographical factors, that can account for the highly irregular distribution of mankind over the earth. The causes are multitudinous and often intricately interwoven. Frequently *sociological factors,* such as the attitude toward the size of the family,

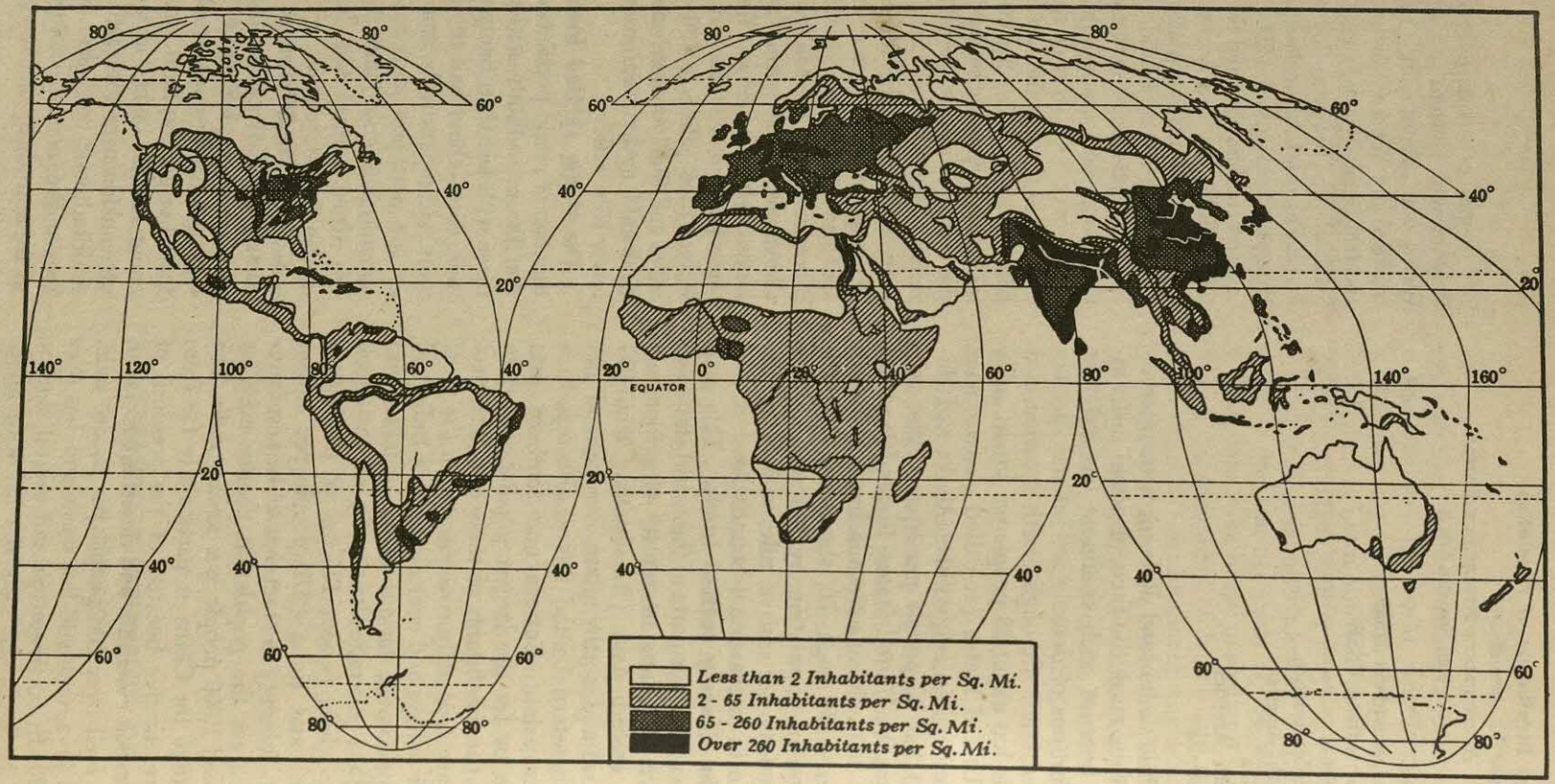


Fig. 10. Density of population of the world. (Goode's interrupted homolosine projection by permission of University of Chicago Press.)

are important. *Stage of technical development* plays an important role. For example, the greater technical knowledge and ability of the American colonists made possible a greater density of population than could ever have been attained by the Indian peoples of the eastern seaboard. Similarly, without the great technical advances which took place during the last century and a half in western and central Europe the present high population densities of the latter areas could not have come about. These advances include not only great improvements in agricultural techniques but also enormous advances in the ability to produce economic goods in large quantities through the utilization of modern power resources, metallic minerals, and machines made out of metals and through better and faster means of communication, better control of epidemics, and many other forms of technological progress.

Other factors which may also play a role are the *historical factors*. The great density of population in lower Egypt may be at least partly attributed to the long history of the Nile valley region.

The *economic factors* are, of course, closely linked with the technological advances that bring about increases in per capita production, but these factors also enter into the picture in other ways. For example, an economic factor that has been of some importance in maintaining dense populations in parts of northwestern Europe is the ability to obtain "outside income," such as revenue derived from investments in other parts of the world, remittances of emigrants, expenditures of visiting tourists, and income from merchant shipping performing services in other parts of the world.

More important and more basic than all of the above, however, are the *geographical factors*. With the aid of modern techniques man can do much to adapt the physical environment to his needs. However, he does not yet know how to eliminate deserts or abolish long, cold winters. Nor can he create deposits of oil, coal, metallic minerals, or fissionable minerals. Where confronted by very poor soils he may discover that such great efforts and expenditures are needed to improve them that it would not be worthwhile. Thus geographical factors often exert a limiting influence. Some cannot be overcome, or, at least, man does not yet know how to overcome them; others can be overcome only if the effort "pays," i.e., brings results sufficiently remunerative to make it worthwhile.

An interesting example of the effects of geographical factors upon population distribution can be found in Indonesia. Here the island of Java and the neighboring islands of Bali and Lombok immediately to the east have very dense populations. Areas of considerable density are also found in certain sharply delimited sections of Sumatra and Celebes. Elsewhere, as in Borneo, in large parts of eastern Sumatra, and in other parts of Celebes and some of the smaller islands, population densities are very low. At first one might think that the suppression of internal warfare under the former Dutch regime as well as western medicine and better-paying crops, which were introduced comparatively early in Java and parts of Sumatra by the Dutch, are largely responsible for these striking differences. However, archaeological investigations have tended to show that this uneven distribution existed long before the establishment of the former colonial regime, when total population was much less than now. The geographical, or comparative, study of soils has shown that the major factor seems to be one of soil fertility. The soils of most of Java, Bali, Lombok, and certain fairly sharply delimited areas in Sumatra and Celebes are highly fertile. These soils are derived from young, basic volcanic material, whereas the soils of large parts of Borneo and the other areas of low population density are derived from old, acidic volcanic and nonvolcanic rocks. The latter soils are badly leached and, though they may support a luxuriant tropical forest, become depleted soon after the forest is cut. The areas of occurrence of young, basic volcanics and those of high population density show strikingly similar patterns when represented on geologic or soil maps and on population maps.

Geographical factors favorable to high densities of population may include, then, the presence of fertile soils, with tempera-

3461
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3461

ture and water conditions suitable to raising a diversity of crops, and comparatively level land; the existence of large and easily accessible mineral deposits which can be used as sources of power; or a geographical location which makes possible easy access to other parts of the world.

The dense population of parts of southeastern Asia depends primarily upon the intensive use of good to excellent soils, land which is well suited for irrigation, and upon a climate favorable for crop growth. In many sections favorable climatic conditions enable the farmers to produce not only a summer, but also a winter crop, and sometimes even three crops per year. Although valuable mineral resources exist in this area, they have been exploited only to a limited extent, and foreign trade is insignificant in proportion to population.

In western Europe soils and climate are favorable for agriculture. Though winter cold is a limiting factor in crop production, precipitation is ample and reliable, and droughts are comparatively rare. More important, however, in explaining the present density of population are, first, the existence of coal, iron, and other minerals, which are mined and used for manufacturing; and, second, the excellent location of this region, facing the North Sea and the Atlantic Ocean, with good navigable rivers—and now also a dense network of railroads and highways—and with many fine ports for carrying on trade within the region and with the rest of the world.

For small countries, such as the Netherlands, Belgium, and Switzerland, the factor of being located at crossroads or at outlets of larger countries with an active trade is particularly important. Northeastern United States resembles northwestern Europe in that it depends for its dense population more upon the exploitation of mineral resources, the development of manufacturing, and an excellent natural location for world trade than upon its farmland (although it has some very good local farming tracts).

Low population densities are frequently the result of unfavorable physical-geographic factors. When this is the case other factors may have little bearing on the situation. Most of the areas with less than two inhabitants per square mile are areas which have an unfavorable climate, such as: (1) the polar and subarctic areas of Siberia, northern Scandinavia, northern North America, and Antarctica, inhospitable because of their cold, (2) the desert and near-desert areas, including the Sahara Desert and the Kalahari region of Africa, the Arabian, Turkestan, and Mongolian deserts of Asia, the great Australian desert, the Great Basin and interior plateaus of the United States, and the dry lands of Atacama and Patagonia in South America, inhospitable because of excessive dryness, and (3) the high plateaus, such as the plateau of Tibet, and the rugged mountain regions, inhospitable because of the cold and the difficult terrain. (See Physical Maps of Continents.)

Arctic and subarctic conditions are reflected in the population density figures for Iceland (4 people per square mile), Canada (5 people per square mile), Alaska (1 person for about 3 square miles), Greenland (1 person per 50 square miles), and Antarctica, which is completely uninhabited. Deserts are largely responsible for the densities of 2.5 people per square mile in Australia, 1.5 in Mongolia, 2 in Libya, 7 in Somalia, 1 in South-West Africa, 0.2 in Spanish Sahara or Rio de Oro. In the United States three of the western intermontane states, namely Idaho, Nevada, and New Mexico, plus the northern plains and mountain states of Wyoming, Montana, and the Dakotas, have less than 10 people per square mile. Arizona and Utah have only slightly over 10.

Where there is not enough heat or water to raise crops only exceptional, local combinations of other factors will result in sizable settlements.

For most arctic areas little can be done to increase the number of self-supporting settlers, except through the development of local mineral resources or transportation centers.

Desert soils can support large numbers of people per square mile only where water is available that has come from more humid areas, as in the Nile valley, where it comes from the south, or in Russian Turkestan,

where it comes from the mountains. The United States is singularly blessed in having the well-watered Sierra Nevada and Rocky Mountains alongside its dry areas, and thus water can come or be brought to such spots as the Imperial Valley of southern California, the Gila river area in southern Arizona, and the small irrigated areas near Reno, Nev. The utilization of water to support oasis populations in desert areas is commonly contingent upon control of water by means of man-made dams. Unfortunately, even if it were economically possible to utilize all available stream and ground-water resources in desert areas, vast tracts of land would still remain dry. Water resources in deserts are very small in comparison with the areas concerned and are easily exhausted. In addition, extensive regions in the deserts have a topography unsuitable for irrigation, while still others have no soil.

In high mountain and plateau regions the length of the growing season is short, good tillable land is comparatively scarce, and agricultural possibilities are therefore limited. An additional drawback is the difficult terrain and the additional difficulties caused in middle latitudes by long, cold, and often snowy winters. Although it is possible to build better roads, expansion of the agricultural area is usually virtually impossible, and industry generally does not seek isolated areas of difficult access.

Low densities are also found in a number of tropical areas where temperatures are high and rainfall is abundant. Most of the Amazon basin has a very low population density; only right near the main rivers it may, in places, have more than two persons per square mile. The Congo basin has, on the average, less than 20 inhabitants per square mile. Other areas of low density in the humid tropics are Borneo and western New Guinea. In these and similar regions possibilities of development are not as limited as in the arid and the icy regions. It is true that in many of these regions the soils may be rather poor even though the forest is luxuriant, and the climate is usually enervating and conducive to diseases in man, beast, and crop. However, carefully planned development, aided by suitable modern techniques and heavy capital investment, may do much to increase productivity and population in these areas. Planning must be preceded by intensive, coordinated geographic study, region by region, if such expensive fiascoes as the ill-fated "Peanut Scheme" in former British East Africa are to be avoided.

Areas of intermediate population density. In the Orient transition is abrupt between the sections with population densities ranging above 200 people per square mile and below 25 people per square mile. Adjacent to the teeming plains of the Ganges-Brahmaputra in northern India or the Yangtze river in central China, are mountains which mark the edge of virtually uninhabited expanses. Only in the zone between India and China is there a sizable area with moderate population densities, between 40 and 100 people per square mile. Here Burma, Thailand, and the other states of the peninsula of Farther India constitute an area where there is a surplus production of the staple oriental grain, rice, over and above the needs of the local producers.

Around the areas of dense population in Europe and eastern United States, on the other hand, the population density decreases gradually. Northern Scotland, Denmark, and parts of Poland, the USSR, the Balkan Peninsula, and the Iberian Peninsula are less highly industrialized and have population densities of generally less than 200 people per square mile. Beyond these regions, to the north, east, and south, population densities decrease still further, dropping to less than two people per square mile in the cold areas of the north, in the dry areas beyond the Caspian Sea to the east, and in the great deserts of Africa and the Near East.

Around the Boston-Washington-Chicago triangle of dense population, the area of intermediate population density, falling within the category of 50 to 100 people per square mile, includes a belt that reaches northward into southern Ontario, westward to the Mississippi river and southward—with interruptions in the Appalachian Mountains—to include the Piedmont region. Beyond this belt average densities drop to less than 50 people per square mile.

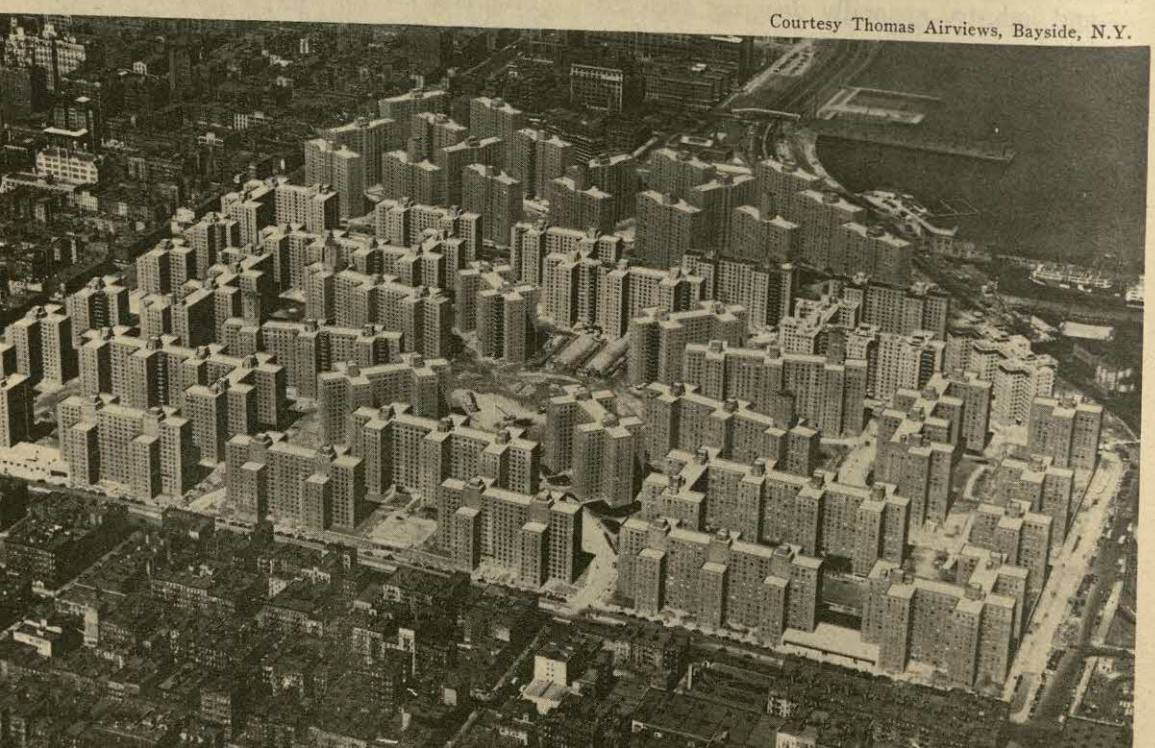
In South America, Africa, and Australia, moderate population densities are found only in small, widely scattered areas, mostly along the outer rims of the continents. Examples in Latin America include the southern portion of the plateau of Mexico, northeastern Brazil, the Rio de Janeiro-São Paulo area in southeastern Brazil, the region around the Río de la Plata, and central Chile. In Africa centers of moderate density are found in the coastal areas of the north, in parts of Nigeria, and in small sections of the Republic of South Africa.

Personal meaning of various densities. Figures of population density will have more personal significance if one can imagine how it would feel to live under various conditions—whether it be in an apartment with neighbors on all sides as well as above and below, as in Manhattan where the population density is over 80,000 people per square mile (Fig. 11); in a small town, where each family has a house with a lawn and garden; on a ranch in Montana (density, including towns, 4 people per square mile), where the nearest neighbor may be several miles away (Fig. 14). These differences in mode of living affect the economic activities, the social practices, and the whole outlook upon life of the individuals concerned. The rancher can hardly be expected to understand fully the economic problems of, or to have the social viewpoint of, the man who lives in a congested metropolitan area. Nor can the urbanite be expected to understand fully the environment, economic problems, and social conditions that confront the rancher. Nevertheless, we all are citizens of a nation and inhabitants of one small world, and to live in peace we must try to have some common understanding, on both a national and international level.

Advantages and disadvantages of dense population. People who live close together usually form a wider circle of acquaintances than do people who live in sparsely populated areas. Under such conditions men who have more than ordinary initiative are likely to become leaders of groups and parties. The development of group activity or teamwork and the growth of individuals into leaders are among the more important results of dense population. It is understandable that much of the politi-

Fig. 11. An example of high density city settlement. Stuyvesant Town and Peter Cooper Village, apartment housing, southeastern Manhattan, New York City.

Courtesy Thomas Airviews, Bayside, N.Y.



cal, social, and religious leadership of today comes from the urban areas.

The ready exchange of ideas encourages some types of literary and scientific development. The existence of a large, compact market favors division of labor and attracts outstanding specialists in many fields. Nearly everyone, whatever his interest or ideas, can find like-minded people in a large city. Furthermore, moderately dense populations are likely to have an aggregate wealth that promotes educational, medical, and social facilities. Modern utilities—electricity, gas, and sometimes even central steam plants—are facilitated by the close spacing of the housing units. Freed from some of the physical chores of existence, many of the city dwellers have time for cultural development.

The denseness of population in urban areas also entails certain disadvantages. Housing space per family is likely to be small, the air impure, and sunlight insufficient. In many neighborhoods there is not enough space for adequate outdoor exercise. Epidemics can spread fast in crowds, and insufficient exercise and lack of sunlight help to weaken resistance to disease. Traffic congestion has become a leading problem of many cities. Even areas of dense rural population (Figs. 12 and 13) do not have such problems as these.

From the social viewpoint there is considerable question as to the desirability of city environment for rearing children. In the city the individual adult, unless he is a leader, may be submerged in the crowd and may lose some of the independence of thought and action often characteristic of the economically independent countryman. In times of depression, city dwellers, most of whom are employees, are severely affected and have no natural products of the land to fall back on for food if unemployed. Recreation is largely commercialized, and many individuals are apt to spend their leisure time in passive recreation rather than in the types of recreation which require individual initiative, be they physical or intellectual.

Advantages and disadvantages of sparse population. The availability of abundant sunshine, pure air, and space and freedom to exercise are some of the advantages from the health viewpoint of sparsely populated areas. The farm commonly provides an abundance of food at reasonable cost and more roomy living quarters. Children in these areas are more likely to find the space and environment that they need for healthy play than are children in large metropolitan areas. The feeling of closeness to nature is an indefinable satisfaction of living where the sunrise, sunset, woods, and streams can be seen in all their beauty.

Certain modes of living have been conducive to philosophical and religious thought. Some of the greatest thoughts were formulated in the Near East by persons who lived in a quiet rural or semirural atmosphere. The solitude of the country, rather than the bustle of the city, is often most conducive to this type of thought (Fig. 14). In countries of heavy snows the winter is sometimes a period of comparative leisure, during which country people can develop their intellectual and social proclivities.

One of the major natural handicaps of sparsely populated areas is the expense, often prohibitive, of providing some of the utilities that make life more pleasant or efficient. Since houses are far apart, it is costly to lay gas lines or, in some cases, even to provide for electricity or running water (Fig. 12). Again, because of the distances involved, there are likely to be no doctors or hospitals readily accessible.

Because recreation involving groups is limited, emphasis is likely to be placed upon the weekly trip to church, occasional fairs, and other special opportunities for group activities. People who live isolated lives can hardly be expected to develop the art of eloquence: they are likely to be quiet and somewhat reticent in conversation, though quick to act when occasion demands.

However, areas of both sparse and dense populations make their distinctive contributions to the life of the nations.

Is a moderately dense population prefer-

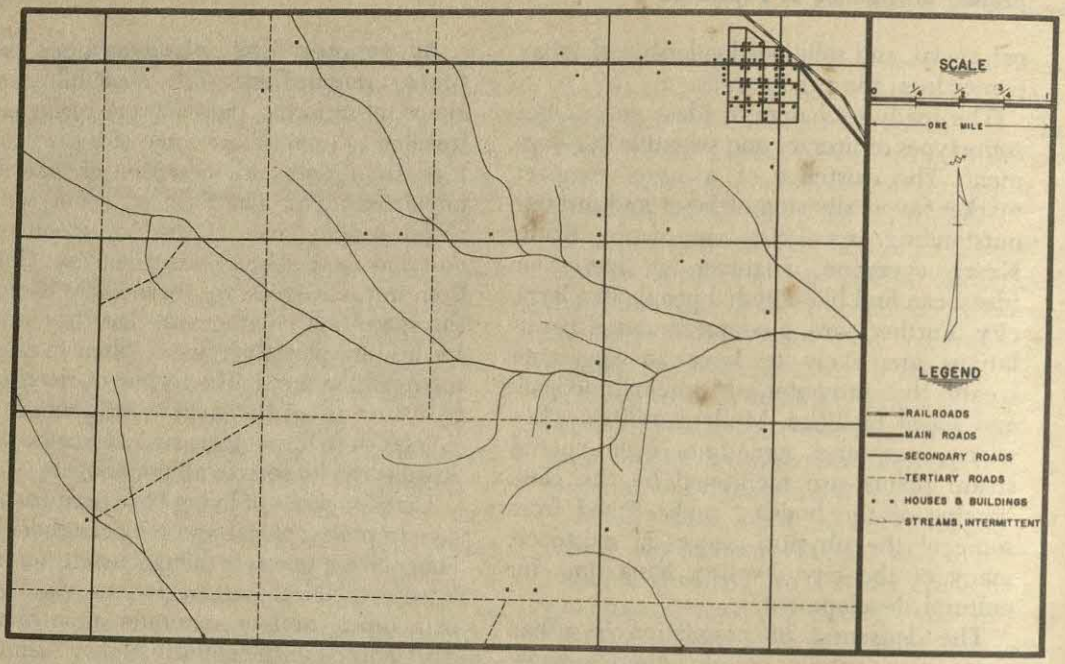


Fig. 12. Sparse population on the High Plains, Nebraska. Adapted from soil survey of Box Butte County.

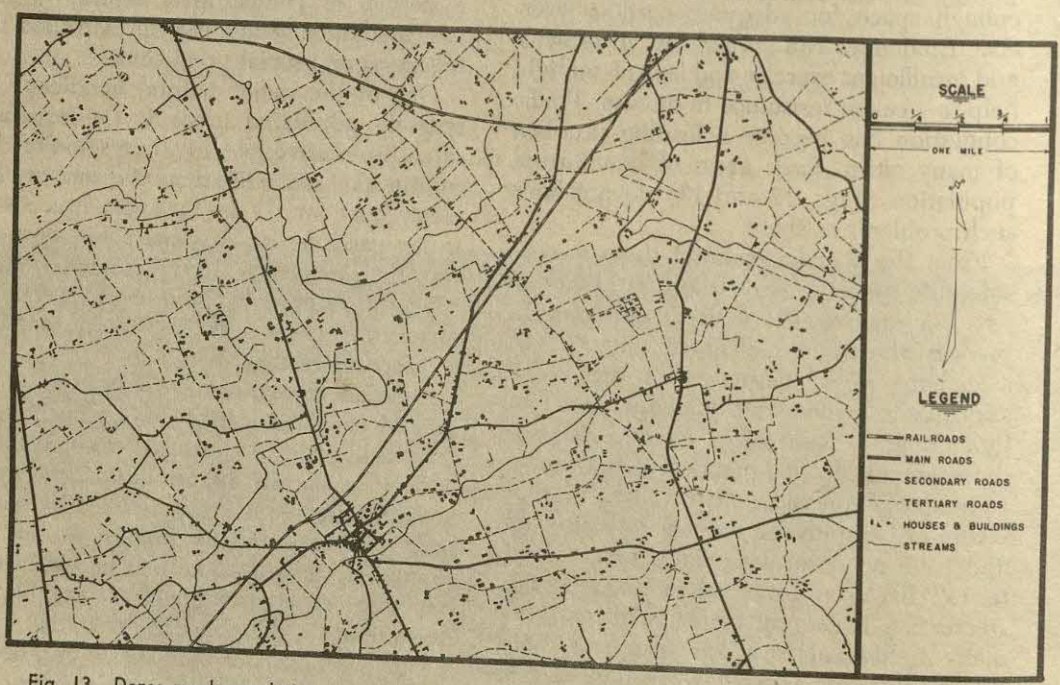


Fig. 13. Dense rural population near Thielt, Belgium. Note that scale of this and the preceding map are the same. Adapted from topographic map of Belgium.



N.A.B.

Fig. 14. Area of sparse settlement, and large ranches and farms in south-central Montana. The man in the photograph is a sheep herder, and while both cattle and sheep appear in the picture, no human habitations are visible.

able to a dense or sparse population? Is life more pleasant there, and is there less friction among the inhabitants? Such questions cannot be answered flatly. There seem to be balanced cultures as well as spots of misery in areas of almost every degree of population density.

ECONOMIC-GEOGRAPHIC EFFECTS OF HIGH AND LOW POPULATION DENSITIES

From the economic-geographic point of view the existence of a dense population is important as it may furnish an abundant supply of labor and constitute a large potential market. The availability of abundant manpower may favor the development of manufacturing industries in an area where adequate raw materials are available. As each new industry is established, or each old one enlarged, the purchasing power of the area may grow, thus enlarging the market for manufactures, agricultural products, and services. The higher the productivity and wages of labor—as a result of adequate resources, technology, skill, management, and capital—the larger the market will be. This compounding process helps explain population increases in new industrial areas.

In sparsely settled areas one of the great handicaps in developing manufacturing industries is the lack of adequate manpower



Fig. 15. The village of Marrum in the northern Netherlands. In many parts of the world farmers and others with related occupations live close together, in small villages, rather than scattered, as is the case especially in Anglo America.

Courtesy Government of the Netherlands and Fototechnische Dienst K.L.M.

and the lack of a sizeable local market to consume the products. For the development of agricultural, forestry, and mining enterprises a good transportation network is essential in order to provide access to major market areas. Unfortunately, in many regions of sparse population the cost of a mile of road or railroad is very high per inhabitant, and most of the capital needed for such construction usually must come from the areas of dense population.

PROBLEMS OF AREAS OF HIGH POPULATION DENSITY

How many people per square mile constitute an optimum? To this question there can be no simple answer. If a semiarid land can support only two herdsmen per square mile, then three persons per square mile would be too many. However, with technical assistance the three herdsmen could perhaps drill a deep well, install a modern pump, and irrigate enough land to support 100 people per square mile over at least a small area.

Nutritionists have estimated that the produce of about two and one-half acres is needed to provide an adequate standard of living for a human being. There are many variables and unknowns in this rough formula, but it furnishes some sort of yardstick for estimating adequacy of land resources. Differences between countries in the per capita amounts of arable land are profound. In comparing two great areas having about 450 million acres of arable land apiece, we find that the United States has more than three acres of arable land per capita, and India and Pakistan together a little more than one. Even without other factors, these differences help to explain the low level of food supply that prevails in the Indian peninsula, as opposed to the adequacy of food supply and the existence of large exportable surpluses in the United States. In China the amount of arable land per capita is also very low. However, in industrial western Europe there is still less arable land. The United Kingdom, Belgium, and the Netherlands have just over one fourth of an acre of arable land per capita, Germany two thirds of an acre, and Italy and Greece three fourths of an acre. Yet the food supply of western Europe is, on the whole, satisfactory. This is the result of high agricultural yields, due at least in part to scientific management, and Europe's ability to import food from other parts of the world in exchange for manufactured goods.

What can be done to solve the problems resulting from a submarginal standard of living? It seems clear that at least one set of measures should aim at improved utilization of resources.

More adequate resource utilization. With the passing centuries, man has continued to learn better methods for obtaining larger production from his resources. The raising of livestock and the practice of agriculture resulted in greater and more dependable output of food per acre. Production has been further increased by the improvement of farm machinery, the use of fertilizers and the discovery of ways of obtaining or manufacturing fertilizers, the use of green manures and compost, the improvement of crop rotations and planting the right crops on the right land, the development of breeds of plants and animals which produce more per acre, and better control of insects. Such methods have a potential for even further development of production and, especially, for further extension.

Significant increases in food production could be made in many parts of the world if farmers would systematically use the techniques and plant varieties best adapted to the conditions of the area. The Food and Agriculture Organization of the United Nations has been carrying on with considerable success educational and aid programs designed to spread throughout the world high-yielding varieties of crops, improved strains of domestic animals, better methods of disease control, and knowledge of sound crop rotation and erosion control.

For an individual country the development of industries through which manpower can be applied to raw materials to turn them into manufactured goods provides one means of obtaining the exchange to purchase food and other necessities from

abroad. Industrial development, however, requires capital and is therefore difficult in countries where the people live too close to the margin of subsistence to have accumulated savings, a basic necessity for capital formation.

CHANGES IN POPULATION AND POPULATION DISTRIBUTION

As yet there are few signs that the enormous growth of world population during the last hundred years or so is beginning to slow down. Although emigration has never solved a population problem anywhere in the world, in the recent past at least large areas in the world could be opened up for denser settlement, so offering possibilities of relief. Geographers of a few generations ago assumed that this process would continue, that other comparatively sparsely settled areas would be opened up, and that thus in the course of time the population of the world would become more evenly distributed.

However, the changes in distribution of population which have taken place during the last half century are completely contrary to these expectations. *Urbanization* in many parts of the world has taken on proportions undreamed of in the past: medium-size cities are growing into large cities, and large cities into huge metropolitan areas.

In the United States the changes in population distribution which occurred during the decades 1930-60 were the greatest since the major westward surge of population during the last century (see Fig. 16). In 1960 the population of most of the counties in extensive areas of the central part of the United States, approximately between the Mississippi river and the Rocky Mountains, was smaller than it had been thirty years before. A similar, but less extensive belt of counties with decreased population extends eastward across the Mississippi river through the states of Mississippi, Georgia, and Alabama into central South Carolina. A third belt extends from western Tennessee and southern Illinois through a part of Kentucky, and from there approximately follows the Appalachian Mountains through West Virginia and Pennsylvania. Throughout all of these areas, however, there are scattered single counties or groups of counties where population has increased, in many cases at a rate exceeding even the average increase in population in the United States during the three decades concerned, which was about 46 per cent. This, of course, reflects the growth of both medium-sized and large cities.

Population increases were general throughout most of the Manufacturing Belt of the United States, approximately from northern Illinois and southeastern Wisconsin eastward to the Atlantic coast. The increases here were especially large in all the urbanized areas, such as those around the head of Lake Michigan, in northeastern Ohio, and in the Washington-Baltimore-Philadelphia-New York-Boston region (this latter area has been referred to as the coming "megalopolis" of the United States). There were increases, mostly above the average, in practically all the counties along the Atlantic, Gulf, and Pacific coasts, and again they were particularly heavy in urban areas, such as the Los Angeles and San Francisco metropolitan areas. In the area between the Rocky Mountains and the Pacific coast region there were both decreases and increases, the latter being especially large in counties that include such cities as Phoenix, Ariz., and Salt Lake City, Utah.

Changes in population distribution of this type are quite general in the world today. In Europe there has been little population growth, or even loss of population in the less-favored agricultural areas, such as northern Scotland, the Massif Central (Plateau Central) of France, the high Alps of France, Italy, Switzerland, Austria, and Germany, and even in some of the more favored rural regions. On the other hand there has been a continued growth of many of the cities, again especially of the large metropolitan areas, such as London and Paris, and the urbanized regions, such as the Ruhr-lower Rhine region of West Germany and the Utrecht-Amsterdam-Haarlem-The Hague-Rotterdam region in the western part of the Netherlands.

In parts of the USSR urban growth has

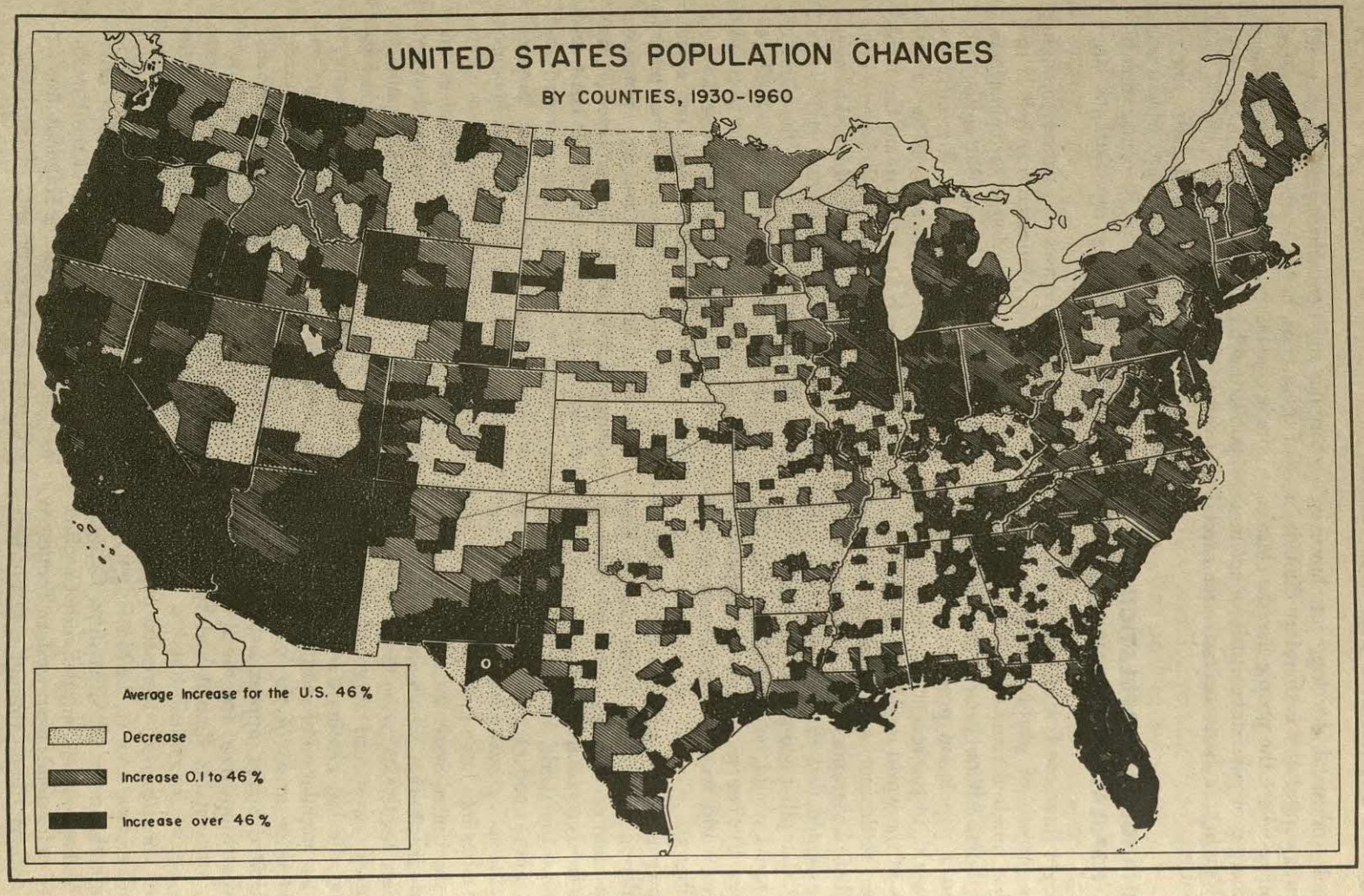

UNITED STATES POPULATION CHANGES
BY COUNTIES, 1930-1960
Average Increase for the U.S. 46 %
Decrease
Increase 0.1 to 46 %
Increase over 46 %

Figure 16.

been rapid and has taken place at least partly at the expense of rural population. Population also gravitates toward the larger cities in countries where there are still large areas which are unsettled or sparsely populated, and where many areas are used only in a very extensive manner, such as in Brazil, Argentina, and Australia. Even in Africa, south of the Sahara, where modern economies exist only here and there, people tend to move toward major centers. To the north and northeast of the city of Dakar, Senegal, in western Africa, for example, lie extensive "urban" areas of native settlement of a most primitive nature, partly regular "shanty towns."

Thus, the present trend appears to be for population in areas of low density to become sparser, and for that in areas of very high density to become even denser.

The increase in world population and the changes in geographic distribution of population are raising very serious problems. Insofar as the changes in distribution are concerned, the present trends may change again. Insofar as the increase in world population is concerned, there is a running argument between some biologists, who say we must reduce the birth rate or submit to brutal reduction by atomic bombs or pestilence, and some technicians in the field of agriculture and resource utilization, who stress the vast increases in production which will be possible as modern research progresses and as its findings become more and more universally applied. To the geographer concerned with a balanced economic development of the earth's surface, it appears that resources and population must be considered simultaneously. A sound geographic goal would be a population balanced at a level which could be adequately supported on the basis of resources available locally and through trade. The attainment of a satisfactory balance is a challenge to the best knowledge and patience of mankind.

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3

The Field and Function of Economic Geography

THE IDYLLIC life of the South Sea island of romantic stories where, with a minimum effort on the part of man, Nature provides all the food he might desire, where clothing is largely decoration, and shelter needs to be little more than a roof, where there is an abundance of time for the less pedestrian concerns of life has been possible only in a few of the world's most favored spots. And even there it was possible only so long as people did not become too numerous. In most parts of the world man has had to go about the business of making a living in dead earnest. This was true especially in areas where Nature has been rather niggardly in providing substances suitable for food, as in the dense tropical rainforest or polar latitudes, or in areas where a winter season or a long dry season might cause seasonal food deficiencies and difficult living conditions. Thus man had to learn to exercise some measure of foresight and also to exert himself in order to acquire, and remain provided with, the basic necessities of life.

In all cases man has had to make his living by applying labor—most of it physical, some of it mental—to the resources at hand. Natural resources occur everywhere in varying kinds, quantities, and qualities, but hardly any are available and ready for instant use and are so abundant, such as air, that they constitute free goods. Most of them are found in limited quantities and acquire utility (or become "utilities" in economic parlance) only as man exploits them, that is, makes them available and suitable for the satisfaction of human desires. Only in this way may resources become real economic goods or wealth.

Unused resources are not real wealth, but merely potential sources of wealth. For thousands of years the vast coal deposits of North America did not constitute wealth to the native inhabitants, and even at present part of these deposits do not constitute wealth, as they may be undeveloped or too deep for successful exploitation by known methods. However, if unused resources are recognized as potential sources of wealth, they become exchangeable for economic goods, and thus acquire value.

The creation of wealth is based upon

man's utilization of natural resources. Since nearly all of these resources are limited in quantity and some are of mediocre quality, and since the total number of inhabitants of this world is increasing rapidly, it is highly desirable that such utilization be as efficient as possible, with a minimum of waste of the resource concerned.

Comfortable living, based upon an optimum per capita wealth for the population of a region, depends largely upon the natural resources which are available in the area or which can be brought to the area. It also depends upon man's ingenuity in adapting such resources to his own use, the physical energy which is at his disposal, and the total number of people whose desires have to be satisfied. Since the prior satisfaction of certain material needs is essential for the development of many of man's higher capacities, material production is basic to the existence of all types of society, primitive as well as modern, simple as well as complex.

However, when depending on his own physical power for the necessary acquisition and transformation of raw materials, and even when aided by the power of domesticated animals or the small-scale use of water or wind, man can produce only at a slow rate and in small quantities. Thus, for thousands of years he could earn his bread only by the sweat of his brow. The average man was never far from a marginal to submarginal mode of existence; his worldly possessions were few, his moments of leisure were rare and brief. Before the so-called Industrial Era, agriculture was by far the most common occupation in the world and the source of a large proportion of the wealth. In fact, individual wealth could generally be amassed most successfully by the big landed proprietors, who had many workers at their disposal.

Since no ordinary person of that time could produce much beyond his own basic needs for subsistence purposes, there had to be a large number of primary producers. Methods of making things were simple and laborious, requiring the aid of hand-tools. Though the quality of the manufactured goods frequently was high—sometimes considerably higher than that of modern machine-made products—the quantity produced was small. Thus the amount of manufactured goods available per capita was small, and, comparatively speaking, prices for manufactured goods were high. Most communities tended to be nearly self-sufficient because they could not demand and did not feel the need for many outside products. However, in locations favored by transportation, traders might engage in an exchange of products. The larger the trading center, the better chance merchants would have to amass individual wealth. This, then, was another means of wealth accumulation.

POWER AND PRODUCTION

In order that the average man may live well and have comforts, leisure, and even a few luxuries at his disposal, not only large amounts of transformable materials are necessary, but the production processes must be carried on at a rapid rate and with the aid of much power. This is especially true where people are numerous and where Nature forces high minimum needs on man, as in the middle and high latitudes.

The human effort, both physical and mental, which is directed toward the production of goods and services, is commonly called *labor*. As a result of man's technical progress, labor now can be supplemented by natural power resources—huge stores of energy which were practically unused during the ages prior to the nineteenth century. Through the use of coal, petroleum, natural gas, and falling water, every average American family has at its disposal, indirectly and directly, the equivalent of probably a couple of hundred theoretical horses working 8 hours a day, 6 days a week.

In the factory. Because of these power resources, it has been possible to reduce the working hours for industrial employees in the United States from 12 to 14 hours a day to 8 hours or less, and in many cases to only 5 days a week.

The extensive use of power, applied through an enormous variety of machinery, permits high specialization of tasks. Al-

though this specialization results in certain evident disadvantages for the indidivual as well as for society as a whole, it does result in production of greater surpluses, which, through the medium of money, may be exchanged for the diversity of things implied in the expression "a high standard of living." Notwithstanding the decrease in working hours, the daily wage has not suffered. The worker in the United States now receives more in real wages for his 6- to 8-hour day than did his predecessor of Revolutionary times for his 14 hours of toil. The workers in the factories have, on the whole, better working conditions than they ever had before, and they enjoy luxuries in food, clothing, and recreation which were unattainable for most people before the industrial era.

On the farm. Large-scale use of power has greatly simplified many of the onerous tasks of farming. The advent of the automobile and the truck brought a great saving of the time formerly spent in hauling products by means of horse-drawn vehicles to a rail shipping point. However, the most fundamental change in this country, and what may be said to amount to the first real agricultural revolution in the history of civilization, did not begin until the middle 1920's and early 1930's, with the invention of the general-purpose or row-crop tractor with power take-off, power lift, and pneumatic tires.

By the end of 1938 about 7,500,000 horses had been displaced by power equipment in the United States. Ever since, the number of horses and mules has continued to decline, dropping to about 10 million in 1940 and to 3 million in 1960. It is estimated that there is a saving of about 65 hours a year in labor for each horse displaced by tractor power, and that the average number of horses displaced per tractor is about 4.4. Thus, by substituting tractors for horses the total reduction in the labor utilized to maintain farm power units runs into hundreds of millions of man-hours. In addition, it is estimated that the average tractor saves 850 man-hours per year on all kinds of work needed on the farm. The number of tractors on farms in the United States increased from 920,000 in 1930 to 3,150,000 in 1948 and to 5,200,000 in 1960. The real agricultural revolution is upon us!

Transportation and economic distance. As long as horse-drawn carriages or wind-propelled ships were the fastest modes of travel and freightage, the earth seemed large and places a few hundred miles away, remote. All transportation was slow, and land transportation was both slow and costly. Only nonperishable goods of high value could be exchanged. Agricultural products of interior lands could not possibly reach world markets, and only products that would not spoil easily could be shipped by sea. Most of the goods needed by man were produced close to the place of consumption and, conversely, supplies of foods and raw materials consisted chiefly of what was locally available.

The world consisted essentially of a large number of small, nearly closed regional economies. With the development of rapid means of transportation and communication, all this has been changed. Trains, fast modern ships, trucks, automobiles, airplanes, telephones, and radios have brought changes more revolutionary than most of us realize. Though its miles remain unchanged, the world has indeed become small. From the viewpoints of trade, communication, and politics the size of the world is but a fraction of what it was in the days of Washington and Jefferson. Then, the voyage across the Atlantic involved weeks and sometimes months of discomfort; now, it can be made by airplane in a comparatively few hours. These changes have made all continents neighbors, instead of areas of little concern to one another because of unbridged distances.

SUMMARY. Thus the relatively high standards of living characteristic of the so-called industrial countries under peacetime conditions are the result of man's use of the machines through which he employs for productive purposes the energy of coal, petroleum, natural gas, and falling water. By utilizing and directing this energy through the machine, man has been able to produce tremendous quantities of goods, in contrast to his low per capita productivity of a cen-

tury and a half ago. The use of natural energy has also enabled him to move himself and especially his goods far and fast, in comparison with the snail's pace of former centuries. The changes in modes of living which have come to the people of the United States and other industrial countries have been far-reaching and profound.

FACTORS OF PRODUCTION

In our modern industrial economy, instead of having to deal with just the four classical factors of production—natural resources ("land" of the classical economists), labor, capital, and entrepreneurship—it is necessary to take into account five factors: (1) the natural resources, including land, which are transformed into capital and consumer goods; (2) power derived from natural resources; (3) capital goods; (4) labor; and (5) management. The tremendous amounts of natural energy which man has learned to tap have made possible both the construction and the extensive use of ever larger and more ingenious machinery, thus greatly expanding the role played by capital goods in our modern economy.

THE IMPORTANCE OF NATURAL RESOURCES

Machines have been known for hundreds of years. The Romans knew and constructed machinery, with many of the parts being made of wood. Machinery was used during the Middle Ages and succeeding centuries, before the so-called Industrial Revolution. Most of this machinery, however, was of the type which allows small applications of muscle power, human or animal, to be made over a longer period of time in order to move great weights. Examples are the pulley and the windlass. (There is really no saving of labor, but there is loss of time.) What is new is the use of power other than muscular power, first through the use of wind and water, later through that of coal, oil, and gas, and now, through atomic energy. This use of natural power has made it possible to create our modern type of economy, which is essentially a *"power-machine" economy.* In order to produce the complicated capital equipment that this kind of economy requires and to meet the demands for increasingly complex consumer goods, not only are large *quantities* of resources needed but also an ever-increasing *variety* of resources.

The subject of economics deals primarily with three important phases of everyday life: (1) production, the creation of economic goods; (2) the distribution of economic goods; and (3) the mechanism of exchanging goods for other goods. This third phase, with its multifarious aspects, such as value, media of exchange, prices, and the working of laws of supply and demand under varying market conditions, has received the most attention on the part of students of economics. But the problems of production are basic to those of exchange, and are becoming more pressing because of increasing specialization of production and the rapid increase in the total population of the world. Basic again to production are resources, of many kinds and of varying qualities, and these resources are affected in many ways by the natural conditions under which they occur. Thus, a study of resources from the economic-geographic point of view—that is, taking into account their distribution as well as the numerous ways in which the natural environment affects their quality and their usefulness—is basic to any understanding of modern economics and modern economic problems.

MAN AND THE NATURAL ENVIRONMENT

Man's technical progress during the last 150 years has been so great, his insight into Nature has so deepened, and his ability to utilize Nature so increased, that he is sometimes inclined to the belief that his ingenuity has finally given him the whip hand and that the physical environment is something of secondary importance—something essentially passive, existing only to serve him as he sees fit. While it is, of course, foolish to believe that Nature ever determined man's mode of life in the strict sense of the word, it is equally foolish to believe that

modern man, through his high technical development, has become independent of Nature. Witness, for example, the problems of recurring droughts, of rapidly silting reservoirs, and of river floods, as well as man's inability to change significantly the weather or climate. Notwithstanding all the artificialities of modern life, especially of modern urban life, man and his various activities can never escape the direct or indirect limiting effects of the natural environment, used here in the broadest sense of the term.

The importance of a differentiated natural environment. If the natural or physical environment were uniform throughout the world; if there were no differences in landforms, rocks, soils, climate, natural vegetation, and crops; if power, metal, and other resources were equally distributed—then the production of material goods would be infinitely simpler, particularly in our modern power-machine economy, which must draw on so many different substances. Although physically such a "world without geography" would be of deadly monotony, economics and other social sciences would have the advantage of being able to devote themselves solely to the problems resulting from the nonhomogeneity of human material and to the general problems of efficiency of production. The sciences of society would be simpler; the problems of society might be easier to solve. However, since profound regional differences in the natural environment do exist, none of the social sciences can afford to ignore or treat lightly the basic geographic realities.

REGIONAL PRODUCTION DIFFERENCES

Because of the basic differences in the natural environment, there are great differences in the kinds of production and economic activities. The life of the Eskimo and that of the forest Negro of Africa afford striking examples. During much of the year, the Eskimo must live under very cold conditions, which make sedentary agriculture impossible. He must obtain raw materials to make the rather elaborate fur and skin clothing that he needs to protect him-

Fig. 17. Eskimo summer hut, Siberia. Note furs and fur clothing on line, and sealskin floats hanging from top of house.

Courtesy Smithsonian Institution



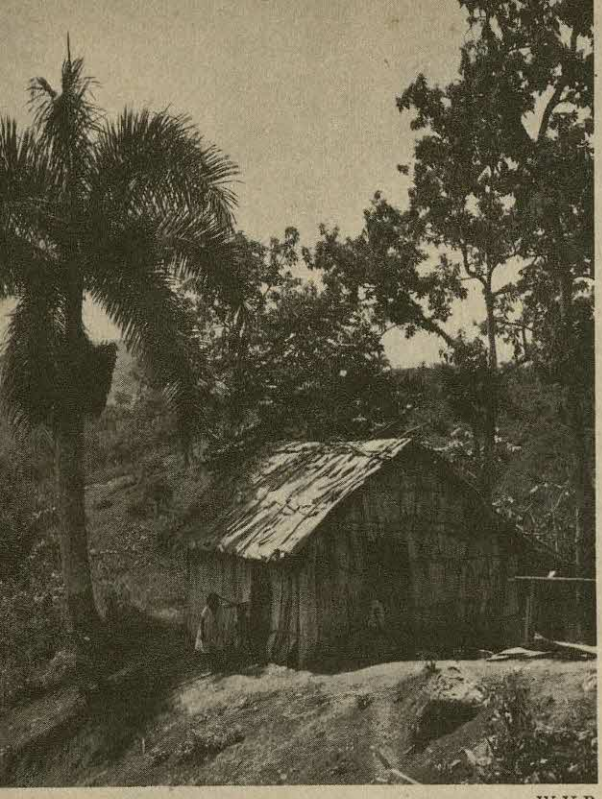


Courtesy Agence Economique de l'Afrique Occidentale Francaise

Fig. 18. Life in the tropics. A Negro village in the northern Sudan of Africa. This is an area with a long dry season. The huts are round, with conical roofs.

self against the low temperatures of the long arctic winter. He needs to construct a sturdy winter house to shelter himself and his family against the severe storms of fall, winter, and spring. He must be able to construct snow shelters, or igloos, during his hunting expeditions, and frequently he must have another type of shelter for the brief summer period (Fig. 17). He has to live on the meat of wild animals, fat or blubber, and fish; to obtain these he must have a sturdy sledge and dog team for winter use and light boats for summer use, and he must be able to carry his supplies, often over long distances. In summer he may supplement his diet by berries and other fruits, eggs, and small birds. Nevertheless, even in the arctic regions the environment does not entirely dictate man's economic activities. In the Eurasian arctic, tribes living under fairly similar conditions have succeeded in taming the reindeer and exploiting the grazing resources of the arctic lands in such a manner that their life is somewhat less hazardous than that of the Eskimos.

The forest Negro of Africa lives in a seemingly friendlier environment. Temperatures are such the year around that he has a minimum need for clothing. Often the clothing that he wears is more for protection against insects than against the elements. Similarly his needs for adequate shelter are much less compelling. A good roof overhead to keep out the beating tropical rains is perhaps the prime necessity and is easily constructed with a variety of Nature's materials (Figs. 18, 19). The growing season may last all year, or at least as long as there is sufficient rainfall, and tillage agriculture can be carried on with relatively little effort. He subsists chiefly on plant foods, although the hunt may provide supplementary animal food. The life of the Negro, then, appears much easier than that of the Eskimo; but the tropical climate is often debilitating, and diseases may take



W.V.R.

Fig. 19. Life in the tropics—A primitive hut in the hills of Hispaniola, Caribbean America. The sides and roof of the hut are leaf sheaths obtained from the type of palm that stands to the left.

a heavy toll, thus creating serious obstacles to more efficient use of available resources. However, modern tropical medicine and modern sanitation are doing much, and may do still more, to make life in the tropics less subject to the ravages of disease. For example, yellow fever, once the scourge of the American tropics, has been nearly eradicated.

The physical environment does not *determine* man's economic activity and mode of life. In the Great Plains region of the United States, for example, the prehistoric Indians were semisedentary agriculturalists; the Indians of historic times, after acquiring the horse, were mostly nomadic hunters; and in the same environment the white man today, although he carries on a multitude of other economic activities, is primarily a sedentary agriculturalist. Still, basic differences in the physical environment cannot be eliminated even by the spread over the earth of the modern power-machine economy. The modes of life of the nomadic Arab of the Near East, the fellah of the Nile delta, the wheat farmer of the High Plains, the fisherman of Norway, the longshoreman of New York, the factory worker of Detroit or Pittsburgh, or the coffee grower of Brazil will never be the same. In each case the physical environment, although it does not *determine* a man's activities, does put certain limits upon the types of things he can produce and the kinds of economic activities in which he can successfully engage, and it also affects what he eats, how he dresses, what type of house he builds, and, often, how he spends his leisure time.

Indirectly, through differences in economic activities and modes of life, differences in the natural environment may even contribute to fundamental differences in thoughts, ideals, and character. The Norwegians, for example, are noted for their vigor and thrift as well as for their prowess in seamanship. In Norway, a country of rugged mountains, thin and stony soil, and a short growing season, the people must face an unusually difficult problem in making a living upon the land. The adjacent sea has been friendlier than the land, and consequently along the western coast numerous Norwegians have turned to it (Fig. 20). For success, however, the sea has demanded courage, strength, and alertness. Thus, through the centuries the stern requirements of life in this northern land have had their effects upon the inhabitants, and only those who could meet these requirements have survived. The Norwegian coastal dwellers of today—virile, agile, and alert—have been influenced as a regional group by many of the factors of the physical environment.

The Spaniards of southwestern Europe are a people whose mode of life and trends of thinking are quite different. The contrasts in the activities and characteristics of the Norwegians and the Spaniards are due to a complexity of factors, but the importance of a different physical environment and the availability of different resources cannot be denied. But even within Spain the Spaniard of the most favored parts of the country—the productive districts of the southern re-



Courtesy Norwegian Information Service, New York; Mittet Foto A/S, Oslo, Norway

Fig. 20. Part of a village on the Norwegian coast. Along much of the coast the rugged terrain leaves little room for settlement. Boats for fishing and other purposes are in evidence everywhere.

gions such as Andalusia—is quite different from his brother of the bleak Castilian plateau. The fertile and sunny coastal plains and valleys have always yielded abundant produce, and the people have not had to contend with the sternness of Nature facing the Castilian.

But one need not go to distant lands to gather examples of important dissimilarities stemming from differences in economic activities. The business heads and clerks who work in the financial district of New York City may speak glibly of "margins," "soft markets," "accept profits," and "stop-loss orders"—terms which may sound ominous and mysterious to the corn farmers of Iowa. Yet the Iowa farmers are keen judges of soil, pigs, and cows and are as expert on farm practices as some New Yorkers are on stock-market activities. The sugar planters of Louisiana live in a world quite unlike that of the sheepherders of Wyoming or the coal miners of Pennsylvania. In each case differences in environment lead to differences in activities, products, and, often, in culture.

Differences in capacity of production. Differences are not limited to kinds of production; there are varying capacities of production as well. Some areas have great actual or potential productive capacity; others have but little, even with the aid of all the most modern means of exploiting the natural resources and modifying the natural landscape. To some extent these differences are expressed in the great contrasts in density of population throughout the world. Parts of Great Britain, France, Belgium, the

Netherlands, and Germany are well endowed with good soils, a suitable climate, large power and other resources and can support densities of population ranging from 125 people per square mile to over 700 people per square mile. Northern Finland and northern Russia have poor soils, a short growing season, few suitable crops, and large forests and support less than 10 inhabitants per square mile. Except perhaps for limited areas, they will never have a population density equal to that of the better parts of western Europe. The plains of Romania, with good soils but frequent droughts, will probably never be able to support as dense an agricultural population as do the agricultural sections of the Netherlands and Belgium, where the soils may not be quite so fertile, but where the climate is more dependable and agricultural productivity therefore higher. On the other hand, the island of Java is well-watered, has fertile volcanic soils in most sections, and can produce two or even three crops per year because of its year-round growing season. It is therefore able to support an even greater density of agrarian population than can the Low Countries. Still greater densities can be supported by industrial districts such as the Ruhr, northern France, central Belgium, and the British industrial districts.

Differences in stage of technical development. The changes in mode of living and the great rise in the standard of living that have come to the people of the United States and the other industrial nations that use power resources and modern machinery have not yet come to many other parts of the world.

At no time in the history of mankind have differences in modes and standards of living been as great as they are today. To a person born and bred in a large city, be it New York, Chicago, Los Angeles, Paris, or London, and accustomed to the amenities of modern city life, it would be very difficult indeed to really understand the way of life and thinking of a group such as the Bindibu of central Australia, who have no huts, practically no clothing, no agriculture and only a few flint and wood implements. For food they gather small animals, such as lizards, and plant products, and they hunt a few of the scarce larger animals such as kangaroos and emus. Almost equally primitive conditions, though with some agriculture, exist among the Papuans of west central New Guinea and in several other fairly remote parts of the world (Fig. 21).[1] Conditions as primitive as these are beginning to be rare, and even in parts of New Guinea the natives have come into contact with Western civilization. Nevertheless, there are still many regions where in comparison with that in modern countries, life is fairly primitive—where people carry on their economic activities much as they have done in past centuries and where they perform the same tasks, think the same thoughts, are spurred to the same types of action, and have the same hopes and fears as their forebears. Such economies in which machines are as yet little used exist not only in the African forest, or savanna, and along the rim of the world's deserts, but also in parts of India and China, and even in many parts of the New World.

SPECIALIZATION OF HUMAN ACTIVITIES

Specialization of activities is an outstanding characteristic of the present age. Instead of one man doing many things and being inefficient at most of them, one man does one certain thing or manages one line of activity and does it well. Individuals, communities, and states have ceased, though often grudgingly and with frequent relapses, to hold to the old idea of self-sufficiency and, insofar as they have not been limited by artificial, restrictive measures, have tended to become efficient surplus producers of a few things, while satisfying other wants by exchange for the surplus products of other regions. On a

[1] See, for example, D. F. Thomson, "The Bindibu Expedition," Part III, *Geographical Journal*, Vol. 128, 1962, pp. 262-278; Peter Matthiessen, *Under the Mountain Wall: a Chronicle of Two Seasons in the Stone Age*, New York: The Viking Press, Inc., 1962, 256 pp.



Fig. 21. Papuans of interior New Guinea, Wissel Lakes region. In the interior of this large island probably from a quarter to a half million Papuans, many of whom still have never seen a white man, live in small scattered groups. Here a white doctor, flown in by plane, is treating sufferers from a tropical skin disease.

Courtesy Government of the Netherlands

world basis, a sufficiency of every commodity essential to human life seems possible if world population does not increase too rapidly and if population becomes distributed more in accordance with the economic potentialities of the different parts of the world than is the case at present.

It will always be true that certain items can be produced more advantageously in some regions than in others, and that some regions will have a surplus of a commodity while others will have a deficit, or may not be able to produce it at all. A much greater degree of regional specialization in the world than is possible at present under the dense web of tariffs, quota, financial, and other trade restrictions would rebound to the benefit of everyone. In fact, such specialization will eventually be necessary if all the inhabitants of the world are to be decently fed and supported. The fulfillment of this need will depend not only upon modern transportation facilities but also upon the efficacy of international social and economic cooperation and organization.

THE IMPORTANCE OF GEOGRAPHIC STUDIES

The economies of regions or countries are created by man and are therefore affected by numerous human factors. However, they are conditioned to varying degrees by the facts of the physical environment—by regional differences in that environment, by differences in the distribution and qualities of the natural resources, and by such differences in the capacity of production as result from the natural environment. While the effectiveness of such influences is usually clear in the case of agrarian regions or industrial regions utilizing predominantly local raw materials, in other cases it may not be quite so clear. For example, even such apparently completely man-made regions as the metropolitan areas of London and New York could not exist without the easy accessibility which was conferred upon them by the physical environment and further improved by man. It may be truthfully said that no analysis of the economic life of a region can have validity unless it explores thoroughly the geographic facts and factors. Some of these facts and factors are physical in nature. A basic understanding of the physical environment remains essential to the proper appreciation of the economic and social superstructure, notwithstanding the highly developed technical skills of modern man—in the final analysis he must still live off and with Nature.

Modern geography embraces both physical science and social science aspects. It attempts, among other things, to relate facts

of the physical environment to those of the social environment and is one of the few sciences that tries to bridge the apparently widening gap between the two great groups of the physical and social sciences. Its position is a difficult one, but an extremely important one.

Physical geography embraces studies of cartography, the elements of weather, climatology, landforms (or morphology of the land), water bodies and drainage, soils, natural vegetation, and animal life. *Social geography*, or *human geography*, in its widest sense embraces economic geography, social geography in the strict sense of the word, political geography, historical geography, and certain other phases of geography.

Economic geography investigates the diversity in basic resources of the different parts of the world. It tries to evaluate the effects that the differences in the physical environment have upon the utilization of these resources. It studies differences in economic development in different regions or countries of the world. It studies transportation, trade routes, and trade resulting from this differential development and as affected by the physical environment.

THE PROBLEMS OF PROGRESS

Industrial civilization of today depends upon the utilization of power and mineral resources. These resources are the keynotes to efficient production. Through them, if rightly used, the world can progress from scarcity to measured abundance, from poverty to relative prosperity. If wrongly used, as for militaristic purposes, these resources can completely wreck all that man has achieved thus far. Through them leisure can be made possible. Rightly used, this leisure may give opportunity for the development of a fine type of culture; wrongly used, leisure and luxury may become forces leading ultimately to the decay and destruction of civilization.

The best possible use of resources is—or, at least, should be—the basis of all modern economic activity, especially in view of the rapid increase of the population of the world. It requires a sound understanding of the nature of natural resources, the various factors of the natural environment, and the relationships of these factors to various types of economies in the world. The goal of economic geography is to contribute effectively toward such understanding. It should lead the student to become a more efficient worker in the economic realm, and, more important, it should enable him to meet more intelligently the problems of citizenship.

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4

The Earth as the Habitat of Man

THE FORM of the earth, its relationships to the sun and its motions, are fundamental to the conditions that make possible life as we know it. The great divisions of land, water, and air spell out the forms that life on earth has been able to take, providing the necessary water and oxygen and permitting suitable temperatures to exist. And the range of life is narrow indeed. Little life activity can take place when the units of life, cells, are cooled to freezing point (32°F.), and little will take place at temperatures of over 120°F. This may appear to be a fairly wide range, but it shrinks to a range of 0° to 50° when expressed in centigrade, and it becomes even less impressive when referred to the real temperature basis, absolute zero, the approximate temperature of outer space. Then the range becomes from 273°K to 323°K, a surprisingly narrow one.

At present scientific interest is centered on the problem of whether some form or forms of life may exist on other members of our solar system. On many of them it seems likely that conditions are radically different from those that permitted life on earth. Still, the existence of life elsewhere in the cosmos is so highly probable that it is almost a certainty. It would be against the laws of probability if the millions and millions of other solar systems did not have planets where natural conditions are quite comparable to those on our own earth.

Here the peculiar conditions of air, land, and water make possible the existence of organic life, and among that the life of human beings. They not only make possible the existence of human beings but, regardless of the stage of economic development attained by man, greatly influence his mode of life and the principal ways in which he supports that life.

The land gives rise to the plains, hills, and mountains that may yield man an abode; it provides the soils for his crops and the minerals for his factories. The water of the seas, lakes, and rivers provides the rain water and irrigation water that make possible agricultural production and that frequently provide him with convenient highways of travel. The air, which gives man warmth or

cold, drove his early ships and mills and now allows him to travel in a manner formerly reserved for birds.

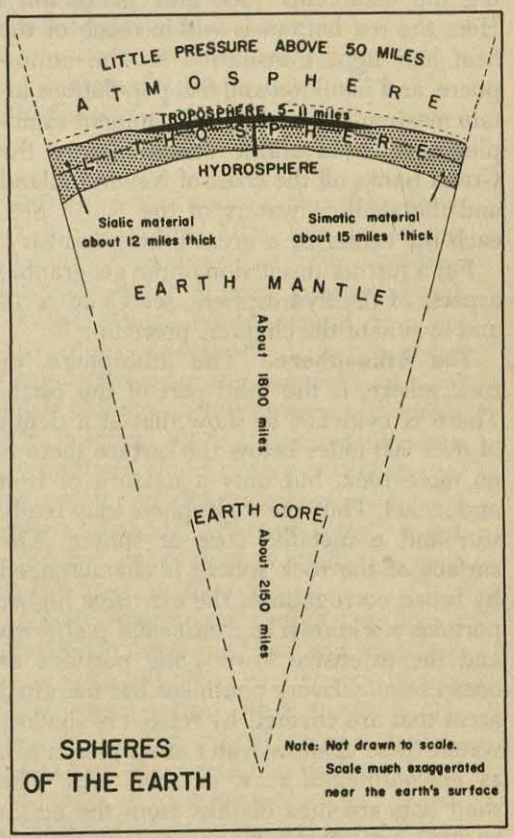
EARTH SPHERES

If we do not take the word "sphere" literally, we may think of the earth as consisting of three roughly concentric spheres: the *atmosphere* (gas sphere), the *hydrosphere* (water sphere), and the *lithosphere* (rock sphere). Plant and animal life occur in all three, but there is no life in the deep interior of the earth or in the upper portions of the atmosphere, and there is but little life in the deeper parts of the oceans. Biological activity, including human activity, flourishes in the zone of contact between the atmosphere and the other two spheres. This zone of life, where plants and animals find optimum conditions of existence, is the principal concern of economic geography (Fig. 22).

The atmosphere. The atmosphere envelops the lithosphere and the hydrosphere and, except for the differential movements of masses of air (experienced as wind), rotates along with the lithosphere. The atmosphere has no very definite limit, and gases occur at well over 200 miles above sea level. However, the density of the atmosphere decreases rapidly upward. The barometer proves that one half of the air, by weight, lies between sea level and 3.6 miles above, and there is little gas pressure at altitudes above 50 miles. The lower part of the atmosphere, where most of the weather phenomena take place, is known as the *troposphere* (sphere of change). The relatively undisturbed air of higher elevations is called the *stratosphere* (layered sphere). The mass, or weight, of the atmosphere is estimated to be about 1/1,200,000 of the mass of the solid earth and 1/270 of that of the hydrosphere. Man lives and moves near the bottom of this atmospheric ocean, the presence of which is so unobtrusive that he forgets its existence except when he feels the wind. Nevertheless it is essential for the life of all warm-blooded organisms, including man. For a discussion of geographic aspects of atmospheric phenomena and atmospheric conditions in their relationships to human activities, see later chapters.

The hydrosphere. The hydrosphere, or water sphere, for the most part fills the depressions of the rock sphere, but because of its penetrative qualities some water is found in the rocks, and much exists in the troposphere in the form of water vapor. The oceans, which cover about 72 per cent of the surface, contain the great bulk of the water. The average depth of the oceans is over 2 miles (about 12,500 feet or 3,800 meters). However, below the general level of the ocean floor, so-called *deep-sea trenches* parallel some of the continental margins and island arcs. Here the greatest depths of the ocean occur. Depths of over 39,000 feet have been found in the western Pacific in the Kuril, Japan, and Marianas trenches, immediately east of the islands of that name;

Figure 22.



in the Philippines trench; and in the Kermadec trench to the northeast of New Zealand.

The earth's water goes through an interesting cycle. By evaporation from the oceans and other water bodies and by transpiration from plants and animals, water enters the air as water vapor, a gas; winds transport part of this water vapor over the land; from the air, moisture is precipitated upon both sea and land; on the latter it forms lakes, streams, soil water, and ground water; from the land it flows back to the oceans or returns directly to the air through evaporation and transpiration. This interrelation of hydrosphere, atmosphere, and lithosphere makes possible the continued existence of plant and animal life. It is evident that the oceans are the major source of water vapor. This basic fact has an important bearing on the distribution of rainfall over the land masses, as will be seen later.

The most favorable conditions for marine life are found in the shallow waters bordering the continents (see next paragraph). Here the sea bottom is within reach of the heat and light transmitted by the atmosphere, and plankton and fish populations attain maximum abundance. Prominent examples of such favorable conditions are the Grand Banks off the coast of Newfoundland and the shallow waters of the North Sea, each the center of a great fishing industry.

For a further discussion of the geographic aspects of the hydrosphere, see Chapter 18 and several of the chapters preceding it.

The lithosphere. The lithosphere, or rock sphere, is the solid part of the earth. There is evidence to show that at a depth of over 900 miles below the surface there is no more rock, but only a mixture of iron and nickel. Thus the rock sphere may really surround a metallic core or sphere. The surface of the rock sphere is characterized by broad corrugations; the extensive higher portions are known as *continental platforms* and the extensive lower-lying portions as *ocean basins.* Every continent has marginal areas that are covered by relatively shallow water; these shallow-water areas are known as *epicontinental seas,* or *shelf seas.* The shelf seas are thus distinct from the ocean basins, and their floors, or *continental shelves,* are really parts of the continents (Fig. 23). As a result of this the real outlines of the continents are quite different from those found on ordinary world maps.

The exposed portions of the continents are generally spoken of as "land." Strictly speaking geographically, the land is that portion of the continental platforms which is not covered by water. However, when water and land areas are given for a country or part of a country, lakes and streams above a certain minimum size are included in the water area, while water bodies below the minimum are included with the land.

Oceans and seas occupy about 70.8 per cent of the earth's surface, leaving 29.2 per cent, or approximately 57,500,000 square miles, for the continents and scattered islands.

Some economists still use the term land to include all natural resources, as distinguished from labor, capital, and entrepreneurship, the other three classical factors of production. This, of course, is a use of the term which is not warranted geographically.

THE FOUNDATION MATERIALS

The land and the ocean basins are underlain by rock. The character of the rock often affects landforms and soils, and thus rocks have a general geographic importance quite aside from their specific importance, such as for mining and quarrying. The characteristics of rocks, in turn, depend to a considerable extent upon the types and arrangements of the minerals of which the rocks are composed. To understand more fully the nature of rocks and their relations to landforms and to economic uses, a brief introduction to the most common minerals will be found helpful.

Minerals. A mineral may be defined as a *natural inorganic earth substance with a definite, essential chemical composition.* Minerals may also contain various nonessential constituents. For example, quartz, the most common single mineral of the land, is essentially a chemical compound of silicon and oxygen. In its pure state it is colorless. However, most quartz has some color due to the presence, in very small quantities, of

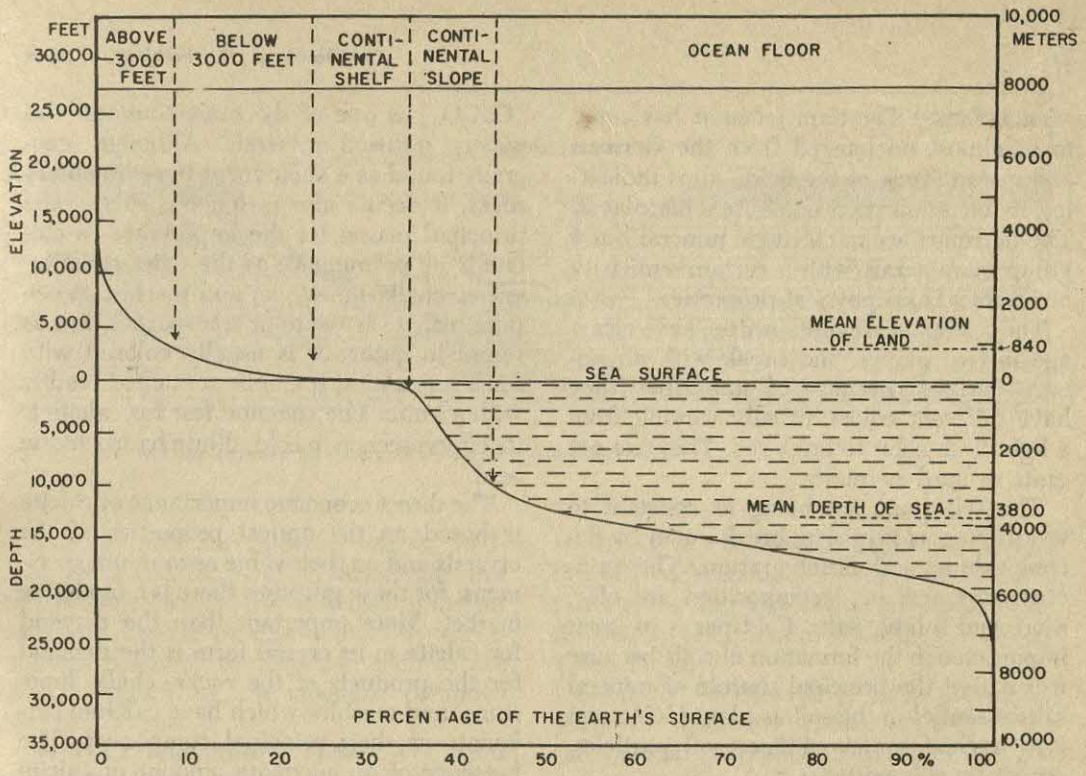


Fig. 23. Extreme altitudes and extreme depths of ocean are both comparatively infrequent. Most of the land lies at altitudes from sea level to 3,000 feet, while the largest part of the ocean bottom lies at depths of over 10,000 feet. Note the rapid increase in depth of the sea beyond the edge of the continental shelf. Epicontinental or shelf seas are less than 600 feet deep.

impurities, such as iron oxide, manganese compounds, carbon, rare earths, and other foreign matter. These items are *not* part of the essential composition.

Although there are more than one thousand different minerals, the common rocks of the land are composed chiefly of a very few minerals. Among these common "rock-forming" minerals are quartz, feldspar, mica, hornblende, and calcite.

QUARTZ. The term *quartz* is applied to a number of minerals of widely different appearance, yet having important characteristics in common. Among the kinds of quartz most frequently found, the following are worthy of special attention: milky quartz, smoky quartz, rose quartz, quartz crystal, agate, jasper, and opalized wood. They have the common quality of a degree of hardness (7) that usually scratches glass, and they are relatively insoluble in water or weak acids. They all have as their essential chemical constituents silicon and oxygen in the ratio of 1 to 2 and are therefore designated by the symbol SiO_2. Because of contained impurities they may differ considerably in color and in physical properties such as crystallization. While quartz does not readily change *chemically*, it breaks down *mechanically* under the influence of temperature changes in the presence of water; that is, it suffers *disintegration* rather than *decomposition*. Upon disintegration the resultant small particles are commonly known as "grains of sand." Although quartz is not the exclusive constituent of sand, it is generally the most common one.

In the soil quartz grains serve a most useful purpose in providing body and friability. Because quartz grains tend to produce a relatively open texture, they facilitate the ready movement of ground water and aeration, and thus the physical condition of the soil is made much more favorable for the penetration of plant roots and for cultivation.

FELDSPARS. The term *feldspar* has come to us almost unchanged from the German and means "rock of the field," thus indicating its common occurrence in some places The feldspars are not a single mineral but a group of minerals with a certain similarity of chemical and physical properties.

The feldspars are quite brittle, have cleavage in two planes, and break with an uneven surface. Because of impurities they have different colors, usually varying from a light flesh color to brick red. They are not quite as hard as quartz.

The feldspars, not being as resistant to weathering as is quartz, break down by decomposition and disintegration. The principal products of decomposition are clay, sand, and soluble salts. Feldspar is of great importance in the formation of soils because it is one of the principal sources of mineral salts essential in the soil as plant foods, and it is a chief source of finer soil particles, especially clay particles.

MICA. The term *mica* is also used for a group of rock minerals rather than for a single kind. The micas are characterized by almost perfect cleavage in one direction and by the thinness and the flexibility of the sheets into which they may split. They vary in color from transparent to black.

Where exposed to weathering, the micas break down into small, flaky particles, but as such they withstand decomposition remarkably well. Small mica flakes are common in many of the rocks which have resulted from the deposition of sands and muds, and they can often be recognized in the soil by their lustrous, shining, and flaky properties.

HORNBLENDE. Hornblende is the most common of the hard, black, brittle, rock-forming minerals. Its hardness is slightly less than that of feldspar. It may be of various colors, but dark brown and black occur most commonly. Hornblende has no direct economic use, and therefore its geographic significance is based upon it being a constituent of several kinds of rocks. It contributes materials to the mantle rock and soil that are somewhat similar to those contributed by the feldspars.

CALCITE. Calcite or calcium carbonate ($CaCO_3$) is one of the most common and widely diffused minerals. Although generally found as a component in sedimentary rocks, it occurs also in igneous rocks. The principal reason for the importance of calcite is its prominence as the chief constituent of chalk, limestone, and marble. When pure, calcite is white or transparent, but as found in nature it is usually colored with some impurities. It can be scratched readily with a knife. The common test for calcite is its effervescence in cold, dilute hydrochloric acid.

The direct economic importance of calcite is based on the optical properties of the crystals and on their value as museum specimens; for these purposes there is a moderate market. More important than the demand for calcite in its crystal form is the demand for the products of the rocks—chalk, limestone, and marble—which have calcium carbonate as their principal component. The presence of an adequate amount of calcite or "lime" in a soil may greatly contribute to its fertility and suitability for tillage purposes. Lime or quicklime (CaO) is made from the calcite of limestone by heating. When slaked with water it becomes slaked lime ($Ca(OH)_2$) for use in mortar and plaster.

Rock. In its broadest sense, rock refers to any of the solid part of the earth. It does not imply any particular degree of coherence or hardness. Even sand, dust, silt, and coal are rock in this broad sense.

On the other hand, the term *stone* implies coherence and is used as a term for some kinds of rocks, such as limestone and sandstone. Thus, ordinary sand, a phase of rock, is called *sandstone* if the sand grains are found cemented together so as to form coherent rock.

In a restricted sense, rock is a *natural earth substance with a specific, characteristic mineral composition.* All rock is composed of minerals. The simplest types of rock are made up of one predominant mineral, such as sandstone, which consists mostly of more or less rounded grains of the mineral quartz. The more complex rocks may contain a large number of minerals. A complex rock, such as granite, contains

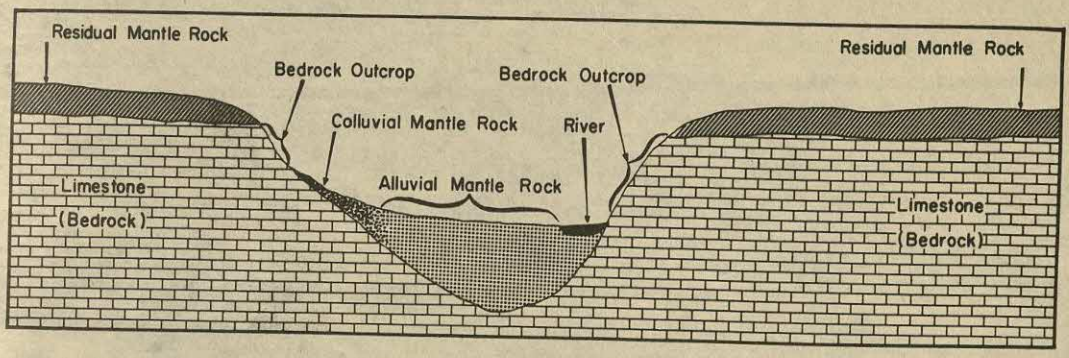


Fig. 24. Relationships between bedrock and some types of mantle rock.

certain characteristic minerals—quartz, feldspar, mica, and, frequently, hornblende—but the proportions of the different minerals vary and cannot be represented by exact, uniform ratios or by formulae such as are used in indicating the chemical composition of minerals.

Bedrock and mantle rock. The solid zone of the lithosphere is commonly referred to as *bedrock*. In most places the bedrock is covered by loose material varying in thickness from a few inches to many and, sometimes, even hundreds of feet. As this debris overlies the bedrock like a mantle, it is known as *mantle rock*. If formed through weathering from the bedrock underneath, it is called *residual* mantle rock (Fig. 24). However, mantle rock may also have been transported to areas where it is found now by water, wind, or ice. In the United States engineers generally refer to mantle rock as "soil," but it will be seen later that true soil is something else.

THE MOST SIGNIFICANT COMMON ROCKS

As bedrock is the fundamental material of which the land is made, and as it has certain direct economic uses, it deserves at least brief consideration. There are comparatively few common types of bedrock, and their principal characteristics can be easily summarized.

Part of the effect of bedrock upon the configuration of the land results from differences in susceptibility to weathering and erosion. When inclined strata of soft and hard rock are exposed in adjacent position, the soft rock commonly wears away more rapidly, forming valleys and lowlands, while the hard rock remains standing as ridges (Figs. 25, 28).

Similarly, in excavating for construction purposes, work can proceed more easily in soft than in hard rock. The depth of bedrock below the surface of the mantle rock also greatly affects construction. Where bedrock is close to the surface of the ground, it impedes the excavation of cellars, canals, and similar works. At the same time, bedrock provides a substantial foundation for heavy buildings, bridge piers, and dams; walls of cellars, ditches, and subways need little artificial reinforcement once they have been carved into the rock. The hard bedrock of Manhattan Island provides a firm foundation for the world-famous skyscrapers of New York and gives permanence and security to its subways, but it caused construction costs to be high.

Where bedrock lies deep below the surface, costs of excavation in the mantle rock for ditches, drainage canals, and basements for ordinary residences and business blocks are low. However, expensive foundations, floors, and retaining walls may sometimes have to be constructed.

For a discussion of the industrial uses of rock, see Chapter 27.

Classes of bedrock. Bedrock is customarily classified, according to its origin, into three main classes: *igneous, sedimentary,* and *metamorphic* rocks. *Igneous,* or *primary,* rocks are formed by the cooling and solidifying of hot molten material (magma)



Courtesy U.S. Forest Service

Fig. 25. Effects of water erosion upon rock strata of different hardness. In this case the strata are almost horizontal, the Colorado River having cut into them deeply. The harder rocks, of course, show the steeper slopes.

Grand Canyon from the south rim at Desert View.

from within the earth. In most igneous rocks, such as granite and basalt, the different minerals, in whole or part, have separated into individual crystals which interlock with one another in the rock. When the magma is cooled deep underground and, therefore, slowly, the crystals grow comparatively large, as is the case, for example, with granite. Later, igneous rocks that have formed at a considerable depth in the lithosphere may become exposed as a result of the wearing away of the overlying rocks. In some instances the magma reached or nearly reached the surface and cooled so rapidly that the minerals did not have time to form larger crystals. The result is a glassy rock, such as obsidian, or a rock consisting of many very small crystals and a few larger visible ones, such as basalt. Rock material which flows out over the surface from a volcano or other opening is finely-grained and is referred to as *lava*. There are many different kinds of lava (Fig. 26).

When exposed rocks have been broken down into small particles by weathering, these particles may be sorted and transported by an agency such as running water and deposited in layers. Such redeposited rock is called sedimentary rock. Clays and shales, sands and sandstones, gravels, and conglomerates are examples. Another example of a rock formed by deposition is limestone, which consists largely of the calcareous skeletons of small marine or freshwater organisms, usually broken or finely fragmented and with admixtures of clay, sand, and other particles of nonorganic origin.

Another class of rock is formed when, as a result of various circumstances, igneous or sedimentary rocks come to lie at a considerable depth in the lithosphere and are there subjected to such intense heat and pressure that they are changed in character, or metamorphosed. These are the metamorphic rocks. Thus quartzite is metamorphosed sandstone, gneiss may be metamorphosed granite, marble is metamorphosed limestone, and slate and schists are metamorphosed shale.

THE IGNEOUS ROCKS. Igneous rocks may be divided into two subgroups, light-colored igneous rocks and dark-colored igneous rocks. Among the rocks of the first subgroup the various types of granite are probably the most important. The mineral components of

granites are essentially quartz and feldspar, and most granites also contain mica and some hornblende. These mineral constituents occur in various proportions and with differences in size and arrangement, and as a result there are many kinds of granite. They occur in various colors; some are light gray, reddish, or brownish, but most are light colored. The structure is wholly crystalline, but the crystals vary from large to small. The granites have a high silica content, since SiO_2 is not only contained in quartz but also in feldspars, micas, and even in hornblende. There are a number of other light- to medium-colored igneous rocks, such as syenite and diorite.

The dark-colored igneous rocks are sometimes referred to as the "basics," and are mostly dark in color. They not only lack quartz, but their constituent minerals are not high in silica content. Thus their total SiO_2 content is considerably lower than that of the granites, for example. The most common examples of this class are diabase, or dolerite, and basalt. In the United States dolerite occurs as prominent ridges in the Connecticut Valley, where it is commonly referred to as *trap*. It also makes up the well-known Palisades of the Hudson river and the trap ridges of northern New Jersey and eastern Pennsylvania. The most extensive area of such rocks in the United States is formed by the lavas of the Columbia Plateau of Washington, Oregon, and Idaho.

Because of its unattractive color, the demand for rocks of this group is limited almost entirely to road-building purposes, riprap work along streams, and railroad ballast. However, these rocks are of importance because they are often a source of comparatively good, though somewhat heavy soils.

THE SEDIMENTARY ROCKS. *Sandstone and Conglomerate.* The terms *sandstone* and *conglomerate* refer to rocks made up of small rock fragments varying in size from very fine sand to pebblelike bodies. If the grains are quite small, the more or less indurated rock to which they give rise is termed sandstone, whereas if the particles are pebblelike, although intermixed with some finer grains, the resulting rock is known as conglomerate. The hardness of the rock depends upon the nature of the material which cements the grains together, the so-called cementing material, which may consist of clay, iron hydroxides, silica and several other substances, singly or in combination. Some sandstones are so compact and firmly cemented that they make durable

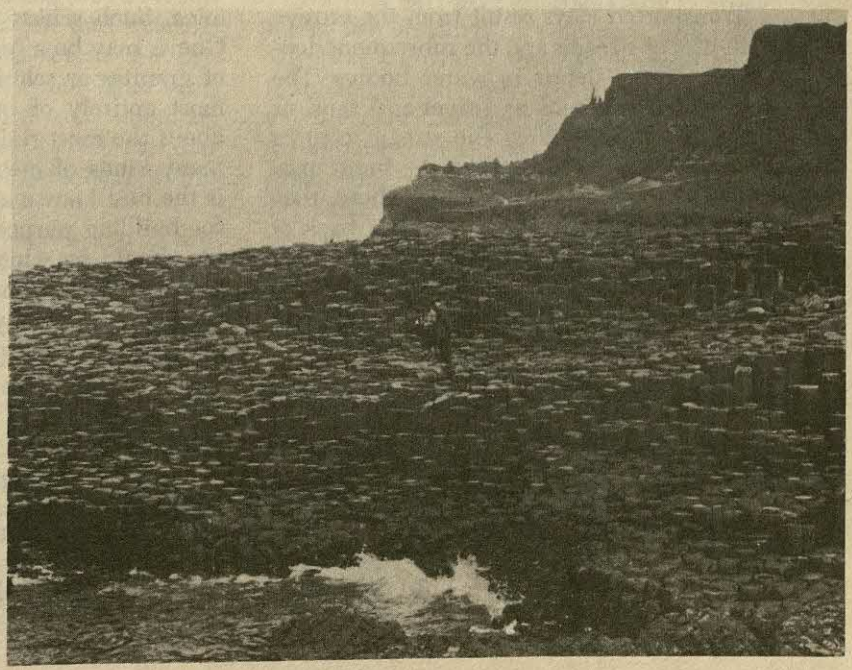


Fig. 26. Igneous rock which has hardened into a columnar structure. Giant's Causeway, Northern Ireland.

Courtesy Associated British and Irish Trailways, Inc.

building material. They are also in considerable demand as crushed rock for use in concrete work.

Clays and Shales. The term *clay* applies to earthy substances of very fine texture, consisting of mixtures of so-called clay minerals, of which *kaolinite* is one, with fragments of other materials of either mineral or organic nature. Consolidated clay is termed *shale,* and the chief distinction between shale and clay is that shale ordinarily manifests a definite tendency to split apart along the planes of deposition. When finely ground and mixed with water, shale very often becomes as plastic as clay.

As to origin, there are two main classes of clay, *residual* and *transported.* Many clays result from the chemical weathering of feldspars, hornblendes, and similar minerals. It will be recalled from previous discussion that the principal products of this type of weathering are clay and soluble salts. When weathering causes the decomposition of feldspars, the salts are carried away in solution, while the clay remains in place (usually with some impurities, such as grains of sand or mica flakes) as a mantle covering the underlying bedrock. Clays thus originating in place through decomposition of the bedrock are classified as residual; in some cases the resulting clays are nearly pure and are known as *kaolin* or *china clay.*

Transported clays result from the erosive activities of streams and the subsequent deposition of the debris in water bodies. The coarse detritus, such as gravel and sand, is deposited mostly along the stream courses or near shorelines, whereas the finest particles are swept farther out, where they settle in stagnant waters near, but back of the actual shoreline, or offshore in the shallow portions of the sea. There they form layers or beds and thus give rise to sedimentary clays, which may be *alluvial* or *marine.* Beds so formed are often many feet thick and of vast extent, but usually do not have as high a percentage of kaolinite and as low a percentage of impurities as do clays formed through the chemical weathering of rocks rich in feldspars.

Limestone. Limestone is essentially calcium carbonate ($CaCO_3$), but ordinarily it contains impurities, such as clay, silt, sand, and various minerals, in varying proportions. In some cases the impurities constitute less than 1 per cent, while in others they may make up nearly 50 per cent of the whole. Limestones vary in color, the grays and light tans being the most common, but other colors, such as brown, black, red, or blue, are not rare. Hardness varies with density and structure; some limestones are soft and porous, others are hard and dense.

THE METAMORPHIC ROCKS. As already stated, the metamorphic rocks are those that have been changed, as a result of high pressures and temperatures, from an earlier primary or secondary form, and sometimes to such an extent that the mineral composition has changed greatly. The most common are known as quartzite, marble, slate, schist, and gneiss. There are various degrees of metamorphism. Shale will first be changed into slate, a fine-grained rock that shows layering which has resulted not from deposition, as it usually does, but from high pressure. Such layering is referred to as *schistosity* or *foliation.* Slate splits easily and smoothly along the schistosity planes, which makes it very suitable for roof shingles, blackboards, and similar purposes. When metamorphism is more intense, visible crystals may be formed as a result of major chemical changes, as, for example, flakes of mica. Such schists are called mica schists. Gneiss may be a product of metamorphosis of granites or schists. Quartzite consists almost entirely of quartz and is, therefore, about the most resistant rock known of the many kinds of metamorphic rocks. Marble is the best known and the most appreciated for building purposes. While statuary marble should be white, as the famous Italian Carrara marble, the attractiveness of marble lies in the many other colors that occur and the varying patterns.

INTERNAL FORCES AND LANDFORMS

The configuration of the earth's surface is the result of the interaction of two sets of forces: (1) internal forces, or forces within



Courtesy U.S. Forest Service

Fig. 27. Volcanic cone, Mount Edgecumbe on Kruzof Island, southeastern Alaska. The crater is well visible, and some erosion of the slopes is evident. Note the forest particularly in and near the gullies. On the whole, the cone is in excellent state of preservation.

the earth, that have raised some parts of the earth's crust and depressed others or that have folded or broken (faulted) the crust, and (2) external forces that tend to wear down the higher portions of the land and build up the lower portions. The forms of the land as we see them today are the result of the interaction of internal and external forces. Often the internal forces are primarily responsible for the major landforms, but these forms are modified, and sometimes even completely destroyed, by the external forces, which will be discussed later in the chapter.

The great continental masses and ocean basins may be the result of differences in the specific gravity of the underlying rocks. The land masses are composed of somewhat lighter, so-called *sialitic* rocks, while heavier *simatic* rocks lie under the ocean basins. The lighter, continental rock masses are supposed to "float" on the heavier simatic masses, as icebergs float on the sea.

The internal forces are largely responsible for the development of the great mountain systems of the world. These internal forces, which may also be responsible for present distribution of continents and oceans, are not as yet completely understood. There are a number of existing theories that attempt to account for the observed facts, but no one of these can be considered as supplying a wholly satisfactory explanation.

The internal forces are commonly grouped under the headings of *vulcanism* and *diastrophism*. Vulcanism involves the movement of molten magma and its outpouring as lava on the earth's surface. Eruptions are often accompanied by explosive releases of gases, which may shatter the magmatic material into small fragments, the smallest of which are called *volcanic ash*. Viscous types of lava, such as andesite, tend to pile up and form lofty volcanic mountains, like Mount Hood and Mount Vesuvius, composed of alternate layers of solidified lava, volcanic ash, and coarser shattered magmatic material (Fig. 27). More liquid types of lava, such as basalt, may create comparatively low, shieldlike volcanoes, such as those of the Hawaiian Islands. If very large amounts of liquid lava are extruded, the lava may spread widely and form lava plains or, if there are a great many successive flows,

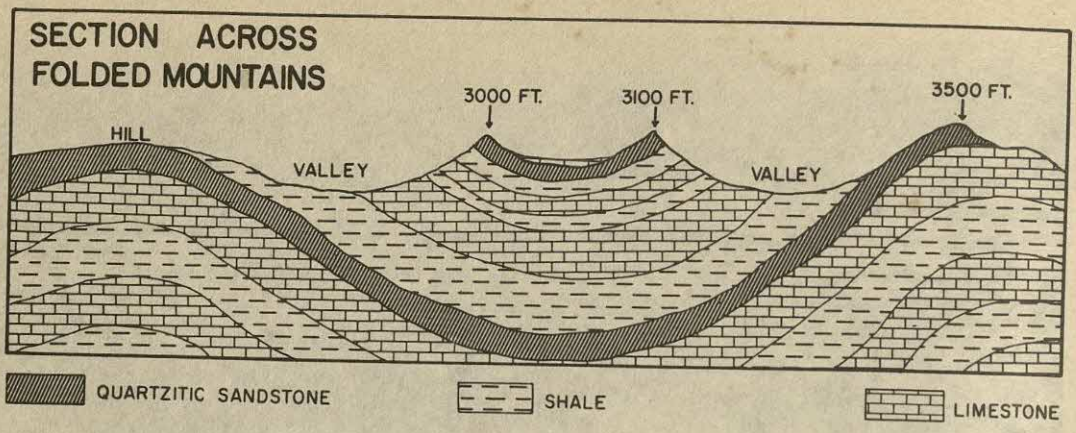


Figure 28.

build up plateaus such as the lava plateau of Iceland or the Columbia Plateau of northwestern United States. Vulcanism is spectacular, but it is often highly localized and is vastly less important than diastrophism in shaping the forms of the land. On the other hand, areas of comparatively recent, but well-weathered volcanic deposits often have fertile soils. This is especially striking in many tropical regions, for example, in Indonesia.

The term diastrophism is used for the internal forces that move existing bedrock. These forces may produce vast, gentle uplifts or depressions of the earth's crust. In this manner, for example, the extensive plateaus of eastern Africa may have been formed. More intense diastrophism may result in *folding*, or fracturing, of the bedrock (Fig. 28). Folding is largely due to lateral pressure and takes place at depths in the lithosphere where rocks are plastic. Later these areas may "bulge up," erosion may take away thousands of feet of rock, and the interior folded structure is thus uncovered. The Appalachians, Alps, and Himalayas are among the numerous folded mountain ranges of the world. Upward and downward movement of portions of the lithosphere along fractures, or *faults*, in the bedrock may create mountains and troughlike valleys. Thus the Sierra Nevada was formed by the tilting of a huge block of rocks toward the Valley of California. This was possible through the existence of a zone of faults along the base of the present steep eastern front of the Sierra Nevada, with another fault zone located to the west of the block. Owens Valley, a troughlike valley at the eastern base of the Sierra, is limited to the east by another fault zone along which the land has risen. Such a valley is called a *fault trough* or *graben*. The upper Rhine Valley, the Scottish lowlands, the Jordan Valley, and the great "rift" valleys of Africa are well-known examples of grabens, where sections of the earth's crust have dropped between parallel fault systems.

THE MAJOR LANDFORMS

From the point of view of man's economic activities, and also from that of the inherent productivity of the land, the nature, extent, and location of the major landforms are of great importance. Plains areas, and to some extent hilly areas, contain most of the population of the world and are often the most productive agriculturally. In some sections of the world, especially in the tropics, plateau areas frequently become important for settlement. Mountains, such as the Urals, may yield minerals or, like the Andes, may act as severe obstacles to transportation. Thus the student of economic geography should have at the very least a basic knowledge of the nature of the major landforms and their geographic distribution over the continents.

The major features at the surface of the earth are *plains, hilly lands, plateaus,* and *mountains*. Although these terms are widely used, it is difficult to sharply define each of these landforms. They may be defined broadly on the basis of altitude, relief, and steepness of slope. Geographically speaking,

altitude is height above sea level of any point. The term *relief* should always be applied to an area and to the average difference in elevation between the highest and lowest parts of that area. For example, an undulating plateau has low relief, even though it may have high altitude. *Steepness of slope* sometimes is even more important than altitude or relief in affecting the cultivation of the land or the building of transport routes. Altitude can be represented much more easily on small-scale maps than can relief or slope, and therefore on many atlas maps land is classified according to categories above sea level, such as 0 to 500 feet; 500-1,000; 1,000-2,000; 2,000-5,000; over 5,000. In the metric system a common classification is: 0-100 meters; 100-200; 200-500; 500-1,000; 1,000-1,500; 1,500-2,500; 2,500-5,000; over 5,000.

The highest known point of land is Mount Everest in the Himalayas, with an altitude of about 29,140 feet. The lowest land is the shore of the Dead Sea in Jordan Valley, which is 1,292 feet below sea level. Thus the extreme relief of the land is 6 miles—a mere surface scratch compared with the 4,000-mile radius of our globe. The extreme relief of the lithosphere, from the top of Mount Everest to the deeps of the western Pacific, is slightly over 12 miles, or three tenths of one per cent of the radius of the earth. It is clear from this that so-called relief globes and even relief maps of continents must grossly exaggerate altitudes, as well as steepness of slopes.

Plains. Plains are lands of low relief and gentle slope. Some areas called plains may actually consist of low hills that have been eroded from land which had less relief in the geologic past. Two major types of plains may be recognized: *coastal plains* and *interior plains*. The former usually have low elevations, rising gently from the shore. The interior plains may be low, but occasionally the term plain is used for level areas that may rise to considerable elevation. Such is the case with the interior plains of North America, which rise to over 5,000 feet at the foot of the Rocky Mountains between the 36th and 42nd parallels. Some of the interior plains may be of the nature of extensive basins, surrounded by higher lands. The lowlands of the world are usually colored green on the type of altitudinal maps referred to above. On United States and British atlas maps everything below 1,000 feet (300 meters) is usually colored

Fig. 29. Edge of a plateau within the area of the Colorado Plateaus in western United States. Photo taken near the San Rafael River, west northwest of the town of Green River, Utah.

Courtesy U.S. Forest Service



green, while on atlases published in the remainder of the world the green color ends at 660 feet (200 meters). This is the reason why in American atlases the world seems to have so much more lowland than it apparently has in many other atlases.

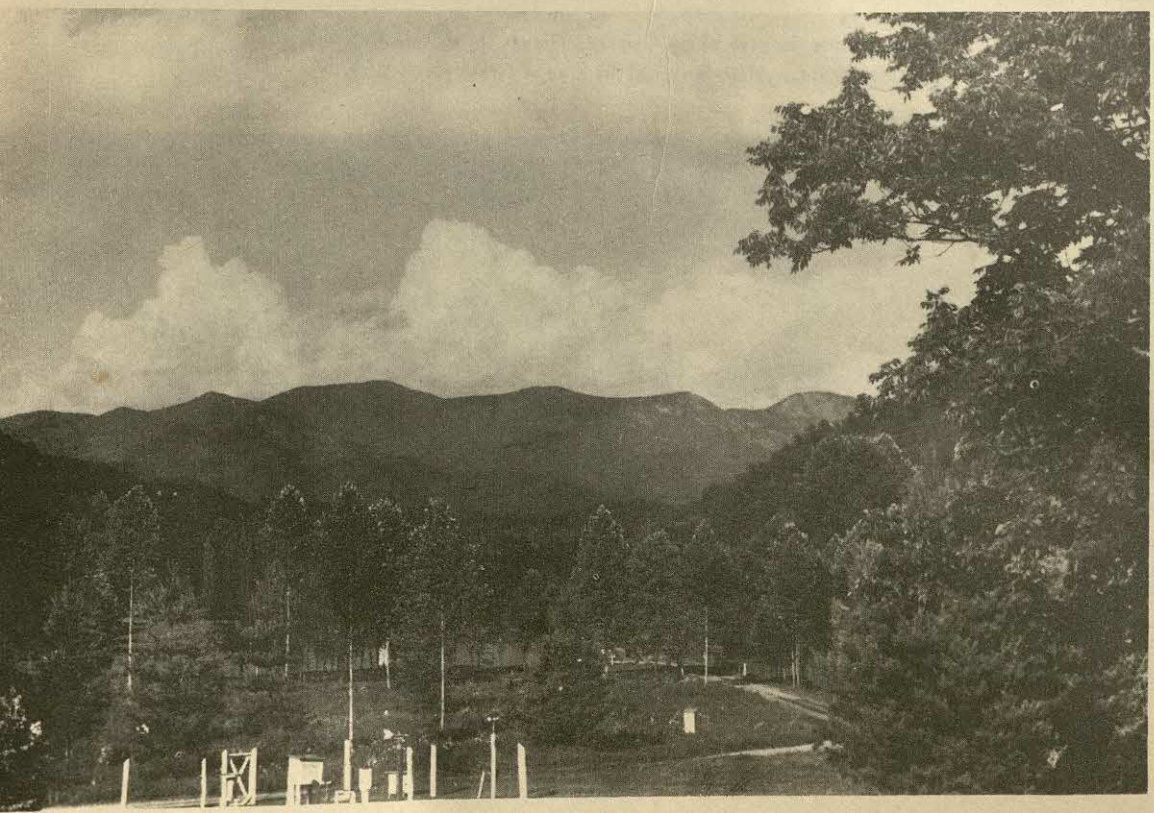
Hilly lands. Hilly lands, which are not as level as plains, but which sometimes may be lower, and which do not have as great relief as mountains, occupy considerable areas in the world. Unfortunately, there is no unanimity of opinion as to exactly what should be called hilly lands.

Plateaus. The term plateau is not too well defined, but in general plateaus are areas of low or moderate relief, lying at relatively high elevations. They are usually set off from adjacent plains or mountains by fairly steep descents or ascents. Among the world's most extensive plateaus are the high plateau (elevation over 10,000 feet) of Bolivia, the so-called Altiplano; the moderately high plateaus (elevation about 5,000 feet) of the African lake district; and the Colorado Plateaus and the Columbia Plateau of the United States. Difference in altitude alone is not the only distinction between plains and plateaus; portions of the Great Plains of the United States are higher than some low plateaus. On the other hand, certain areas, like the Appalachian Plateau of the United States, are called plateaus even though they consist in large part of steep-sided hills and mountains. They were plateaus in the geologic past, but only small patches and strips of the original plateau surface remain, the rest having been cut away by erosion. Geographically, such areas are mountain or hilly lands rather than plateaus. Similarly the so-called plateau of Tibet is really not a plateau, as it is crossed by many mountain ranges and relief increases from over 1,500 feet in the western part to over 6,000 feet in the central portion,

Fig. 30. Mountains that do not rise above the tree line. Forms fairly smooth. Referred to in geographical literature as "middle mountains," a literal translation of the German "Mittelgebirge."

View in the Southern Appalachians of North Carolina. Note the meteorological station in the foreground.

Courtesy U.S. Forest Service



and to even larger figures in the eastern sections (Fig. 29).

Mountains. Mountains are lands of relatively great relief and steep slopes, with small summit areas. Altitudes are usually considerable, but not necessarily.

As there are many different types of mountains, it is quite difficult to generalize about them. The term is used rather loosely and may refer to a single elevation, such as Stone Mountain in Georgia near Atlanta, or Mount Katahdin north of Bangor in Maine, or to a small area with several high elevations, such as the White Mountains in northern New Hampshire. It may also refer to enormous systems of ranges with many high peaks, multitudinous spurs, and intercalated deep valleys, such as the Himalayas in Asia.

As has been mentioned previously many mountains are the result of folding or faulting. A useful distinction is the one between folded mountains and block-faulted, or *block mountains*. Folded mountains can be divided into comparatively *young folded mountains* and *old folded mountains*. The latter have been in existence so long that they have lost much of their height. Sometimes old mountains are "bulged up" again, either as a whole or only in parts; in the latter case the parts are separated by areas which have remained low. Such mountains can be called *rejuvenated mountains*. These distinctions are used on some of the continental maps which precede the text.

From the point of view of economic geography there is an important distinction between mountains that are covered to their summits with vegetation and those that rise above the tree and grass lines (Fig. 30). The completely vegetated type provides more opportunity for forestry and grazing, and, in addition, it is usually less rugged and more rounded of slope, thus forming less of a barrier to movement than the other type. To this type belong such mountains as the Great Smoky Mountains and the Coast Ranges along the Pacific in the United States, and the Jura and the Black Forest in Europe, all with wooded or grassy rounded slopes and sheltered coves.

Mountains with barren peaks rising above the lines where trees and grass can exist are called of the *Alpine type* because of their resemblance to the Alps of Europe (Fig. 31). The higher parts of such mountains often contain permanent snow and ice fields from which glaciers descend toward the valleys. The unprotected rocky upper slopes are attacked by weathering, and sharp peaks and ridges are the result.

Other types of regions which it is useful to classify separately are the so-called *shields*. These are areas of very old rocks, mostly metamorphic and igneous, where ancient mountain ranges have long ago been eroded away. Their relief is usually minor, with higher remnants of more or less importance rising here and there. The best known example is the Canadian Shield. Areas of this type are often rich in metallic minerals.

GEOGRAPHIC DISTRIBUTION OF MOUNTAINS. Although mountains occupy only a small percentage of the earth's surface, they are conspicuous and frequently impressive. They have distinctive significance from the viewpoint of economic geography. The major mountain ranges of the earth occur in two principal belts or systems: the Circum-Pacific System, which extends around the Pacific Ocean, and the Alpine System, which runs roughly west-east through northwestern Africa, southern Europe, and Asia. The first system carries a series of active volcanoes along the crest of the Andes, through Central America, Mexico, California, Alaska, Kamchatka, Japan, and the Philippines and is sometimes popularly referred to as the "Rim of Fire" of the Pacific. Folding and faulting have built up mountain walls in this zone, which includes the Andes, Sierras, and Rockies of western America. Earthquakes are common in many sections. Lines of islands, the peaks of mountain ranges mostly submerged below the ocean, are links in this Circum-Pacific System; among them are the Aleutians, which run from Alaska to Kamchatka; the Kurils, from Kamchatka to Japan; and the Ryukyus, from Japan to Formosa.

The second system of mountain ranges is referred to as the Alpine System after one of its best-known members, the Alps of Europe. It extends from Morocco and Spain



Fig. 31. Mountains of the "Alpine type," i.e., mountains that rise above the tree line. High pastures in the foreground; rock, snow and ice at high altitudes. View in Switzerland.

Courtesy Official Information Bureau of Switzerland in New York. Photo by G. Müller

to New Guinea. To it belong such well-known mountains as the Himalayas, Hindu Kush, Elburz, Dinaric Alps, Carpathians, Apennines, and Atlas. Near and within it lie plateaus and plains, such as the plateaus of Iran, Anatolia, the Spanish meseta, and the plains of Hungary and Walachia.

EXTERNAL FORCES AND LANDFORMS

With the limited vision imposed by his short tenure of life, man is inclined to look upon the mountains of the earth as symbols of eternity. Among some primitive peoples the mountain tops are thought to be the sites from which the spirits of the departed forever watch over their descendants. In Japan, Fujiyama symbolizes all that is old and hallowed by tradition and all that lasts while generations come and go. The cosmic order, however, recognizes no such thing as permanence, and even the most majestic mountain systems are subject to that fundamental law of Nature which decrees everlasting change.

Wherever bedrock is exposed to the air it is attacked by forces that lead to its disruption. Other forces transport the rock fragments downhill. Some mountain peaks, apparently consisting of solid rock, are so thoroughly decayed at their summits that a famous Alpinist once exclaimed: "Give me a crowbar and I will lower them!" (Fig. 32). Mountains, and whole mountain systems as well, wear away, although at a rate so slow that only by studying the results can man grasp the significance of the forces and processes involved. In Europe the low mountains and hills of Belgium, Brittany, and central France once probably reached Alpine heights. In the United States, the Appalachian mountain system has suffered immense erosion in the long course of its existence.

From the point of view of economic geography it is fortunate that mountains are not the permanent features of the landscape that they are commonly believed to be. Most of the mantle rock of the earth is the result of the slow decay of mountain masses, and the mantle rock is the parent material out of which soil may be developed through the action of various weathering and leaching processes and by changes brought about by microorganisms. Soils are the essential base for all plant growth and for agriculture (see Chapter 7). The nature of the mantle rock depends to a considerable degree on how it was formed.

Rock decay or weathering. The first step in wearing down mountains is rock decay, or weathering, induced by exposure to the elements and the attacks of organisms. As mentioned earlier in the chapter, weathering may involve only the mechanical breaking up of rock masses into smaller



Fig. 32. Mechanical weathering is extremely active in high mountains above the snow fields. Note the jagged appearance of the sharp ridges, which results from such weathering. These peaks stand above the Juneau ice field in Alaska.

Courtesy U.S. Forest Service



Fig. 33. An isolated mountain that rises sharply above the tree line: Mount Hood in Oregon (11,250 feet). It is a volcanic cone on top of the Cascade Range. Photographed from Chinidere Mountain (4,675 feet).

Courtesy U.S. Forest Service

particles (disintegration), or it may involve complete changes in the chemical composition of the constituent minerals of the rock (decomposition).

DISINTEGRATION. This is an important process in desert regions and in high mountain areas where a protective vegetation cover is absent and where there are sharp contrasts between day and night temperatures, which result in the cracking of bedrock. Also, expanding, freezing water in rock cracks will enlarge these. The cracks gradually penetrate deeper and deeper into the rock and thus pave the way for complete disintegration. Frost weathering prevails where moisture is abundant, where the temperature changes frequently from above to below freezing point, and where there is little or no vegetation cover to protect the bedrock. Such conditions exist above the tree line (Figs. 32 and 33) in high altitudes, in high latitudes, and in middle latitudes during the winter season.

DECOMPOSITION. Water is the chief agent

in the decomposition of rock. Pure water is chemically inactive, but water nearly always contains other matter, and some of it may occur in ionized form. As the raindrops descend from the clouds they gather carbon dioxide and oxygen; as they percolate through the soil, humic acids and other chemicals may be incorporated. Water so fortified can effect the crumbling and eventual wasting away of any rock.

Chemical weathering practically ceases at temperatures below freezing and is therefore unimportant in high mountain or polar regions. High temperatures accelerate it, and thus chemical weathering is most active in the warm, moist tropics, where rock sometimes weathers to depths of over a hundred feet. In regions such as the Congo, the Amazon basin, or Indonesia, outcrops of solid rock are rare and are usually found only in stream beds. Because this is generally true even in areas of considerable relief, exploration for minerals is difficult in tropical rainy regions. In desert areas chemical weathering plays only a minor role because of the lack of moisture.

Erosion and deposition. As soon as rock has been broken into smaller pieces by weathering, it becomes susceptible to being moved, either by gravity only or by such agents of transportation as running water, waves and currents, ice, or wind. The various modes of transportation of rock debris are called collectively *erosion*. The transported materials eventually come to rest as *deposits* at lower levels.

The direct work of gravity is apparent in the debris that covers the lower slopes of extensive rock outcrops. If slopes are high and steep, fragments pile up at the base in steeply sloping accumulations known as *talus* (Fig. 34). Less spectacular, but really

Fig. 34. Bedrock is exposed near the top of the mountain, but its flanks are covered by mantle rock, loose debris resulting from weathering. Such accumulations on the flanks of mountains are referred to as talus. In the foreground probably alluvial mantle rock. Deschutes National Forest, Oregon. Broken Top Mountain (Elevation 9,165 feet).

Courtesy U.S. Forest Service





Photo by N.A.B.

Fig. 35. Boulders in stream bed of Big Thompson Creek across front range, Colorado. These boulders are moved when the water is high but remain lodged during low-water stages. When moved they scrape the stream bed and are reduced in size by grinding against the bottom and one another.

much more important, is the slow downhill mass movement of finer mantle rock on gentler slopes.

Gravity, together with surface washing of particles, transports to streams the material that makes up the greater part of their sedimentary load. Streams and other agents of transportation can carry the rock debris much farther than gravity alone. In this manner much debris—sands, silts, and clays—is carried downstream and even to the sea for deposition beyond the coast on the continental shelf.

The results of erosion may be either harmful or beneficial to man's economic interests. In high mountain regions, which are usually sparsely populated, erosion does relatively little direct damage to human interests, but in lower, hilly areas much good soil, after plowing, may be carried away by water, to the detriment of agricultural productivity. In parts of the United States, for example, erosion accelerated by man's activities, so-called *sheet erosion*, and resulting from unwise land use, is an ever-present problem. On the whole, however, normal erosion is more useful than harmful to man because that which rivers, glaciers, or wind transport, they must deposit somewhere. All the valley bottoms and most of the plains areas of the world have resulted from the deposition of rock waste removed from higher areas. For example, much of the upper bedrock and mantle rock of the Great Plains of North America and of the lowlands of northwestern Europe was derived either directly or indirectly by erosion from adjacent mountain areas. It should, of course, be understood that these are processes that involve geologic ages, not time as usually measured by man in decades or centuries.

WATER EROSION AND DEPOSITION. Streams are the most important agents of erosion and deposition over much of the earth's surface. The erosive capacity of streams depends upon their size and their velocity. Those that have steep gradients and much water can carry great loads of boulders, gravel, sand, and finer particles. With the aid of this load, especially of the coarser particles, streams can carve into the bedrock over which they flow. Thus they deepen their valleys and extend them headward farther back into the uplands. At the same time the network of minor streams becomes more dense: as a plant constantly grows new roots, so a river grows new tributaries. In this manner all the higher land finally is dissected by river valleys, and the hills and mountains in between are slowly worn away (Fig. 35).

Streams tend to assort their load according to size. In or near mountains large boulders are deposited in the stream bed.

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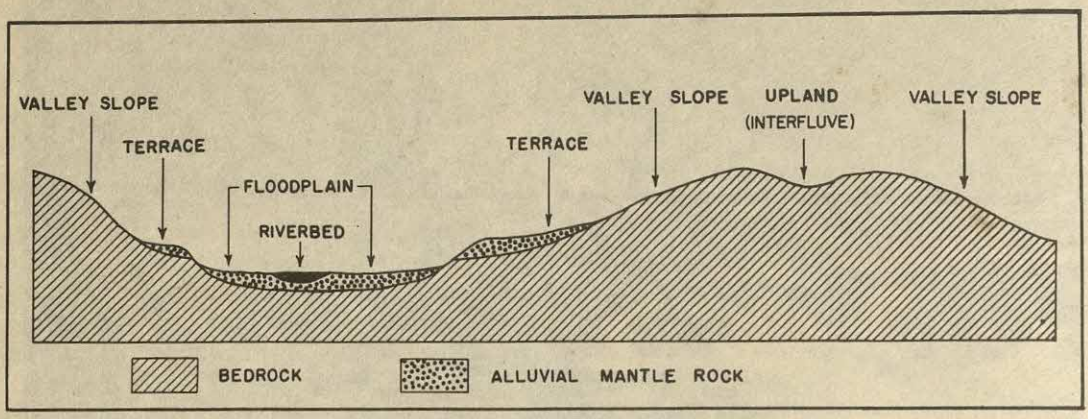


Fig. 36. Cross-section through a typical river valley, showing principal landforms.

Gravel and sand are dropped farther downstream, where the gradient is gentler and the current less swift. The finest particles, silt and clay, are carried as far as the lower part of the stream course and to the sea. Of course, short rivers with a steep gradient may even carry very coarse material to the sea.

Any rock debris deposited by running water is called *alluvium*, one of the several types of mantle rock. Alluvial mantle rock is characteristic of all floodplains and delta regions. The term *floodplain* is applied to that part of a river valley which is subject to flooding during times of very high water (Fig. 36). When such flooding occurs the velocity of the river water is checked slightly as it spreads laterally. This may result in the deposition of fine, suspended material, which will add to the fertility of the floodplain, but sometimes, especially in the middle courses of streams, it may cause deposition of infertile masses of sand and gravel. Floodplains with deep alluvial soils, like those in the valleys of the Nile, Ganges-Brahmaputra, and Yangtze rivers, constitute some of the most densely settled agricultural areas in the world.

If for some reason a stream that has been building a floodplain begins again to cut downward, parts of the old floodplain may survive as *terraces* (Fig. 36). Because of their safety from floods and their good drainage, stream terraces are important not only for farming but also as sites for towns, roads, and railroads.

Alluvium, deposited at a river mouth in a shallow lake or sea, forms a *delta*. Delta lands may be extremely fertile when reclaimed; witness the rich, densely populated deltas of the Rhine river in the Netherlands, the Red river in Indochina, and the Si-Kiang in China.

In arid areas, where streams dwindle away before reaching the sea, the drainage is "interior"—the entire load of detritus is deposited on the land. Streams terminate in basinlike areas, *playas* or *bolsons*, where during the rainy season or after a single heavy rainstorm the water spreads out in a thin sheet. During dry spells this surface water evaporates and may leave glaring white expanses of accumulated salts.

Still other types of landforms resulting from water action are those caused by *waves*. Here again both erosion and deposition are important. The waves, especially along the seacoast during storms, may pound against the land with great violence. The coast is thus cut back, leaving steep cliffs if the land is sufficiently high. The debris eroded from the land is carried to sea by the undertow and drifts along the coast with the currents and waves. Much of this debris is sand and may be blown onto the land again and form *barrier beaches* and *coastal dunes*. In quieter water silts and clays are deposited. *Marine clays* and *silts* frequently are very fertile, such as the marine-clay lands along many parts of the coast of western Europe.

GLACIAL EROSION AND DEPOSITION. Ero-

sion and deposition by ice profoundly modified much of the surface of the earth during the Ice Age and still continue to do so in the polar regions and in the high mountains of the middle latitudes. During the Ice Age huge sheets of ice, called *continental ice sheets,* probably several thousand feet thick, formed in the northern parts of Europe and North America and spread southward until about one half of each continent was covered. Similar, but smaller continental ice sheets formed in northern Asia, southern South America, and a few other places. The evidence shows that probably four successive *glaciations* occurred, each extending slightly varying distances (southward in the Northern Hemisphere and northward in the Southern Hemisphere) and separated by long, practically ice-free interglacial periods.

The slow forward movement of these enormous masses of ice during thousands of years resulted in a thorough scouring of the surface, especially near their centers of origin. Mantle rock and prominent bedrock masses were carried away and ground away (Fig. 37). Basins were excavated in the bedrock. As a result of this, areas like Finland, northern Sweden, and the Canadian Shield of north central and northeastern North America have extensive areas of exposed bedrock, sparse mantle rock, myriads of lakes, and rivers with many rapids and waterfalls. In such areas agricultural possibilities are limited, and the most economical use of the land often is for forestry.

In a wide belt near the margins of the ice-covered areas, deposition prevailed over

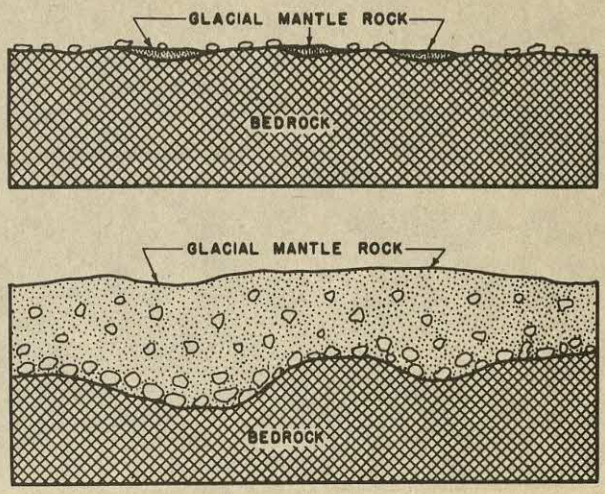


Fig. 37. Upper cross-section shows a scoured glacial plain where the continental glaciers have removed much material, as in northern Canada. Lower cross-section shows an area where glacial deposition has been much greater than glacial erosion.

erosion, and with the melting of the ice its rocky burden was left as a mantle of varying thickness, often smoothing over a quite irregular bedrock topography underneath (Figs. 37, 38). A large area in North America, between the Great Lakes and the Ohio and Missouri rivers and including most of New York state and all of New England, was thus covered by glacial mantle rock. In Europe, similar material forms the surface of part of the British Isles and of a belt of land which extends from there eastward through the Netherlands, Germany, Denmark, and Poland into northern Russia.



Fig. 38. Glacial morainic topography in southeastern Michigan. Note irregular, hummocky hills left by melting of ice with consequent deposition of contained rock debris.

Photo by N.A.B.



Fig. 39. During the Ice Age this valley was completely filled with ice. The present snow and ice fields are of very little volume in comparison with the tremendous amounts of ice under which this area was buried during the Pleistocene. Note how the valley was rounded, and widened to U-shape and how rocks were smoothed below the present snow line.

Courtesy U.S. Forest Service

Glacial debris may be coarse or fine and either dropped by the ice directly or by the waters which issued from the ice through melting. The mantle rock dropped by the ice is commonly referred to as *glacial drift.* It can easily be distinguished from alluvium because alluvium is well sorted according to the size of particles, whereas glacial drift is an unassorted mixture of rock fragments of differing sizes. Sometimes glacial drift is loamy (a mixture of sand, silt, and clay), with large and small boulders scattered through it, and in this case it may yield good soils. In other places the drift may be very stony or sandy and soils may be formed upon such drift which from an agricultural point of view, may be marginal. In New England the numerous glacial boulders made tillage difficult, and the colonial farmer, with unending patience, picked out the stones, large and small, and piled them into mile upon mile of stone fence. These stone fences are still one of the most characteristic elements of the New England landscape.

WIND EROSION AND DEPOSITION. Whereas water erosion is most active in humid regions, wind erosion is more effective in arid and semiarid lands. In deserts and near-deserts vegetation is sparse, active weathering provides much loose material, and the particles are too dry to adhere to one another. Fine gravel and sand are swept along the surface by strong winds, while the finer particles—such as very fine sand, silt, and clay—are carried suspended in the air. As a result of the transporting activities of the wind, the desert surface tends to become rocky and gravelly in some sections and sandy in others, while the very fine, dustlike material may be deposited in peripheral areas. Sand, in accumulations behind obstructions, or as a thin, patchy veneer over rock, is omnipresent in deserts. Sometimes huge accumulations of sand occur, forming dune deserts, or "sand seas," and known in geographical literature by the Saharan term of *erg.*

Material finer than sand may be carried by the wind in the form of dust storms over considerable distances, and upon deposition may give rise to extensive deposits of *loess,* which, in turn, have given rise to some of the world's most fertile soils. The most striking characteristic of loess is its porous but coherent structure, which enables it to stand almost vertically in cliffs, with little tendency toward sliding and slumping. Loess deposits occur in three types of regions: (1) on the margin of desert areas, (2) near areas of former continental glaciation, and (3) adjacent to the valleys of some major streams. This suggests that the loess was blown out of: (1) desert areas, (2)

areas that were glaciated during the Ice Age and before vegetation had re-established itself, or (3) wide floodplains during the Ice Age. The most extensive loess regions are found in northern China, southern European Russia and southwestern Asiatic Russia, and the central part of the Missouri-Mississippi drainage basin in the United States. The principal handicap of loess soils from an agricultural point of view is that they occur mostly in semiarid and subhumid regions of undependable precipitation.

Thus the external forces are largely responsible for three things: (1) the partial, and eventually even almost total destruction of major landforms, especially mountain ranges and plateaus; (2) the creation, transportation, sorting, and redeposition of debris which often forms new major landforms, such as coastal plains; (3) the creation of a host of minor landforms, such as floodplains, deltas, ground moraine plains, etc., often of signal importance to the economic geographer because of inherent differences in productivity.



Fig. 40. Valley deepened and broadened by continental glaciation. Geiranger Fjord, the upper portion of Stor Fjord, inland from the town of Ålesund, Norway.

Courtesy Norwegian National Travel Office



Fig. 41. Grass-covered dunes and sandy road in the Nebraska sandhills.

Photo by N.A.B.

MAPS

One very important function of the geographer is to represent the earth, and larger and smaller parts of it graphically, showing lands and seas, rivers and lakes, height of the land and depth of the sea, forms of the land, villages, towns, roads, and railroads, and often a host of other matters, such as climates, use of the land, natural vegetation, types of products, etc. *Cartography*, the making of maps, is one of the major subdivisions of the field of geography.

The earth is most accurately represented by a globe. Such a miniature replica, although requiring much generalization, avoids distortion of the major earth features. Inasmuch as globes are bulky, and curved surfaces are not practical for use in books or atlases, there is an imperative need for some means of representing the earth, or parts of it, on a plane surface. This need raises the important problem of how to represent the surface of a sphere, or a portion of it, on a flat surface without serious distortion of size or form. A sphere, or even part of a spherical surface, cannot be made into a flat surface without some distortion, as will become apparent if one attempts to flatten out even a small part of a deflated rubber toy balloon. While this may not be much of a problem if one wishes to represent one square mile of the earth in cartographic form, for larger areas, states, countries, and continents the problem is real. It has therefore become necessary to devise methods whereby the earth's surface can be portrayed in a flat plane with a minimum amount of distortion. No map is a true picture of the area represented. The larger the part of the earth portrayed by the map, the greater, of course, is the distortion.

No map, however carefully it may be drawn, can accurately represent both form and size of an area at the same time. Since maps are made to serve specific needs, methods have been devised whereby faithful representation of the particular features desired is achieved, though this usually entails sacrifice of accuracy in other features.

Maps are important for all aspects of geography, including economic geography, which makes extensive use of maps, not only of the types showing surface features, political division, settlements, etc., but also of specially devised economic maps. For a further discussion of maps and map projections, see the Appendix, page 589.

MAJOR LANDFORMS OF THE CONTINENTS

By considerably simplifying maps of the continents it is possible to make major landforms and landform regions stand out clearly so that the principal mountains, plains, and other areas, many of which will be mentioned in following chapters, can be located with comparative ease. A detailed study of each of the continents with the aid of a good modern atlas will, of course, show

that actuality is far more complex than the schematic maps preceding this text.

North America. The west side of North America, from Alaska to Panama, is occupied by young folded mountains which are part of the Circum-Pacific System. The Rocky Mountains of the United States, Canada, and Alaska are a major constituent, as are the Cascades-Sierra Nevada of the states of Washington, Oregon, and California. Within this area of young folded mountains there are high plateaus, such as the Columbia Plateau, the High Plateaus of Colorado, and the plateau of Mexico; regions of block mountains, such as the Great Basin; and a few plains, such as the Valley of California. In the northern part of the continent lies the immense Canadian Shield, which reaches into the United States in the states of Minnesota and Wisconsin. The Appalachians, which have an outlier west of the Mississippi river, are old, highly eroded mountains. Parts of this area, such as the so-called Appalachian Plateau and the Piedmont, consist mostly of hilly lands.

Great interior plains reach from the Arctic Ocean in the north all the way into Texas. Parts of these plains, especially near the central Rocky Mountain front, are quite high, attaining altitudes of from 2,000 to over 5,000 feet.

The Gulf-Atlantic Coastal Plain is the most extensive coastal plain in the world, reaching from Cape Cod, Mass., and Long Island, N. Y., far into Mexico.

South America. Again, on the west side lies a member of the great Circum-Pacific System, the Andes. There are a number of high plateau areas within the Andes, as can be seen by reference to a good atlas. An important low area is the Great Valley of Chile, between Santiago and Puerto Montt. The Guiana Shield is extensive, and parts of it are little known. Like the Canadian Shield, it appears to be rich in minerals, and at present it yields iron, bauxite, manganese ore, and gold. There are a few sandstone plateaus on top of the Guiana Shield, and they provide some of the higher altitudes, such as Mount Roraima (about 9,000 feet high). The Brazilian Shield, to the southeast, has a more mountainous topography, especially in its southern portions. The Brazilian plateaus to the west occupy a very large area, the surface consisting mostly of younger rocks, especially sandstones, although in many places older rocks are found, similar to those of the Guiana Shield and the Brazilian Shield. The northwestern portions of this region are still little known. There are many narrow, and some wider coastal plains in South America, and in three places these merge with interior plains. Thus the Guiana Coastal Plain, across the delta of the Orinoco river, opens onto the Llanos Interior Plain. The delta plain of the Amazon river merges westward into the great Amazon Interior Plain, which is also still little known. The plains at the Rio de la Plata, on which Buenos Aires is located, merge into the extensive Pampas-Gran Chaco Interior Plains. Patagonia consists mostly of low plateaus. Although many people still think of Africa as the dark, unknown continent, in actual fact much of Africa is now well-known, except, perhaps, for small portions of the Sahara Desert. Today, the only extensive unknown or little-known areas, outside of Antarctica, are found in the interior of South America away from the main navigable rivers.

Africa. Northernmost Africa is part of the other great system of young mountains, the Alpine System. Throughout the remainder of the continent, with the exception of a small area of older folded mountains at the southern tip, the processes of folding occurred so far back in geologic history that any mountains that may have existed have been eroded away completely. Much of Africa is a land of horizontal and subhorizontal surfaces. The bevelled, ancient rocks are exposed in the Guinea Shield; in the Ahaggar, Aïr, and Adrar mountains of the Sahara; and also in many of the low and high plateaus of central and southern Africa. There are a number of extensive, basin-like interior plains where younger, mostly unconsolidated sediments have been deposited: the Congo, Kalahari, Upper Nile, Chad, and Upper Niger plains. The Low Plateaus and Plains region of Northern Africa consists largely of consolidated sedi-

mentary rocks, frequently forming low plateaus bounded by steep escarpments, and of loose, younger deposits of sand or silt, while in places the foundation of ancient rocks comes to the surface. The remainder of the continent consists mostly of high and low plateaus. Among the former, the best-known are the High Plateaus of Ethiopia and Eastern and Southern Africa.

Europe. This is one of the most complex continents, and it was necessary to simplify the map greatly. Southern Europe is dominated by young folded mountains of the Alpine System: the Alps proper; the Apennines, Pyrenees, and Sierra Nevada to the west; to the east, the Carpathians, Transylvanian Alps, Balkan Mountains alignment and the Dinaric Alps-Pindus Mountains alignment. Included in "Alpine Europe" are a number of small plains and some large ones: the Po, Hungarian, and Walachian plains. Also included are some areas of old folded and partly eroded mountains: the Rhodope massif in the east, and the Spanish meseta in the west. The latter has high, level, plateau-like surfaces and mountain ranges standing above them, the former is well dissected and quite mountainous.

The eastern part of the continent is taken up by the Eastern European or Russian plains, which are level to rolling and which reach as far as the Ural and Caucasus Mountains. Somewhere in Poland these plains merge with the Western European plains, which include the plains of eastern England, as these latter are separated from the main body of plains only by the continental shelf of the southern North Sea and the English Channel. Between the Western European plains and the Alpine System lies a very complex area of blocks of worn-down old folded mountains, now mostly level to rolling on top; hilly lands; and plateaus and plains. Another area of worn-down old mountain blocks and of small plains lies west and north of the plains of eastern England. The Highlands of Scotland are part of this area. The same old folded mountains, somewhat less worn down, continue northeastward into Scandinavia. Between the Scandinavian Mountains and the Eastern European plains lies the Scandinavian Shield, the European counterpart of the Canadian Shield, though much smaller in extent.

Asia. This is a huge continent, with a great variety of surface features. The Arabian Peninsula as far east as the Gulf of Oman, the Persian Gulf, and Mesopotamia, really is a continuation of Africa. The Red Sea to the west of it is part of a great system of grabens that leads southward deep into Africa, but in the case of the Red Sea a portion of the earth's crust sank so low that the sea could enter. This has made a somewhat artificial division between Africa and Asia. Old rocks are exposed on the west side of the peninsula, and here the land is often mountainous. Most of the peninsula, however, as is the case in the region west of the Red Sea, consists of younger rocks, frequently forming low plateaus bounded by steep escarpments, and of loose, younger deposits of sand and silt. Mesopotamia, with its two major streams, the Euphrates and Tigris rivers, is a flat, interior plain between the peninsula and the Alpine System to the northeast.

The Alpine System enters Asia from Greece. It occupies most of Asia Minor (Turkey), Iran (Persia), and Afghanistan, as well as part of northwestern Pakistan. Eastward of the high Pamir in southern USSR the system reaches enormous heights and width. The Karakoram and Himalaya Mountains constitute probably the most spectacular mountain region of the world, with many famous peaks, such as Mount Everest (Chomolungma), Annapurna, Mount Dhaulagiri, Godwin Austen, and a host of others. North of the well-known town of Darjeeling (just south of the Sikkim boundary) the Alpine System attains the enormous width of about 800 miles. Its northern border is formed by the Altin Tagh Mountains. The intervening Tibetan Plateau is not really a plateau, but a series of high, roughly west-east trending ranges with intermontane valleys, basins, and hilly areas.

At about the 100th meridian east the entire mountain system bends sharply southward and becomes much narrower. It con-

tinues through eastern Pakistan and western Burma into the Indonesian archipelago: western Sumatra, Java, the Lesser Sunda Islands, and Celebes, meeting here the Circum-Pacific System.

The Indian Peninsula, much of which is occupied by the Plateau of Deccan, lies south of the Alpine System and is separated from it by the Indus and Ganges interior plains.

To the north and northeast of the Pamir region lie a series of west-east trending, old folded mountain ranges which, as a result of the great pressures that accompanied the making of the high, Alpine chains to the south, were uplifted, and which as a result of rejuvenated erosion have again become impressive mountains. To these belong the Alai, Tien Shan, Altai, Great Altai, and Sayan Mountains. To the west of these rejuvenated mountains lie the Plains of Turkestan and the Kazakh Uplands, an old badly eroded and nearly leveled mountain area. North of the latter, and between the Ural Mountains and the Yenisey river, lies one of the great lowland areas of the world, the West Siberian Plain. Unfortunately, much of it is located rather far north. Between the Yenisey river and the Aldan river, a tributary of the Lena, lies the Central Siberian Low Plateau. Beyond this lie the mountains and basins of northeastern Asia and, mostly to the east of Lake Baikal, the Transbaikal region, a fairly mountainous area of ancient rocks. The Tarim-Gobi High Plains lie in the middle of the continent, at altitudes of 2,500 to 4,500 feet.

Eastern Asia is another rather complex area. Eastern China consists of the South China Hills, the North China Plateaus and Plains and the Manchurian Plain. To the east of the latter, in China and adjacent Korea, lies an area of old mountains which shows considerable relief and attains altitudes of 8,000 to 9,000 feet in northern Korea. The peninsula of Farther India, as mentioned before, is occupied in its western part—western Burma—by the Alpine System of young folded mountains. To the east lie the highly dissected older mountains, plateaus, and plains of Farther India.

Along the east coast of Asia lie parts of the Circum-Pacific System, in Kamchatka, Japan, in the Philippines, and elsewhere.

Australia and New Zealand. Much of western and central Australia is a very level area underlain by ancient rocks, the Australian Shield. Here and there small mountain ranges rise above it, such as the Macdonnell, Musgrave, and Hamersley ranges, with maximum altitudes of 4,000 to 5,000 feet. In places some younger rocks lie atop the older ones, as in the Nullarbor Plain, a flat, featureless surface measuring about 450 miles from east to west. There are extensive areas of sand dunes, such as the Great Sandy, Gibson, and Great Victoria deserts. Along the east and southeast coast lie the Australian coastal ranges. They are comparatively low in the north, rarely rising above 2,000 feet, but become considerably higher south of the latitude of Brisbane, especially the New England Range, the Blue Mountains, and the Australian Alps. In the latter the altitudes rise to well over 6,000 feet. Between the mountains and the coast lie small and larger coastal plains. To the west of the mountains lie two large interior plains, the Great Artesian Basin with mostly interior drainage and the Murray-Darling Basin.

New Zealand is an area of young mountains rising to heights of 10,000 feet and over, plains, and hilly lands. It belongs to the Circum-Pacific System of young mountains and, like other parts of this system, such as Kamchatka and Japan, has volcanoes and volcanic phenomena.

MOUNTAINS AND ECONOMIC ACTIVITIES

Even in areas of rugged mountains there are commonly ways in which a sparse population can make a living. Agriculture ordinarily can be carried on only on the floors of the lower valleys. In the mountains animal industries are more important than tillage agriculture. In many mountains of the Alpine type there is a zone above the tree line and below the snow line where grasses and other forage plants flourish. This vegetation furnishes summer pasture for cattle and sheep, and a seasonal migration de-

velops between these summer pastures and the winter headquarters in the valleys below. Such *transhumance* is common in the western United States as well as in the mountains of Europe and Asia.

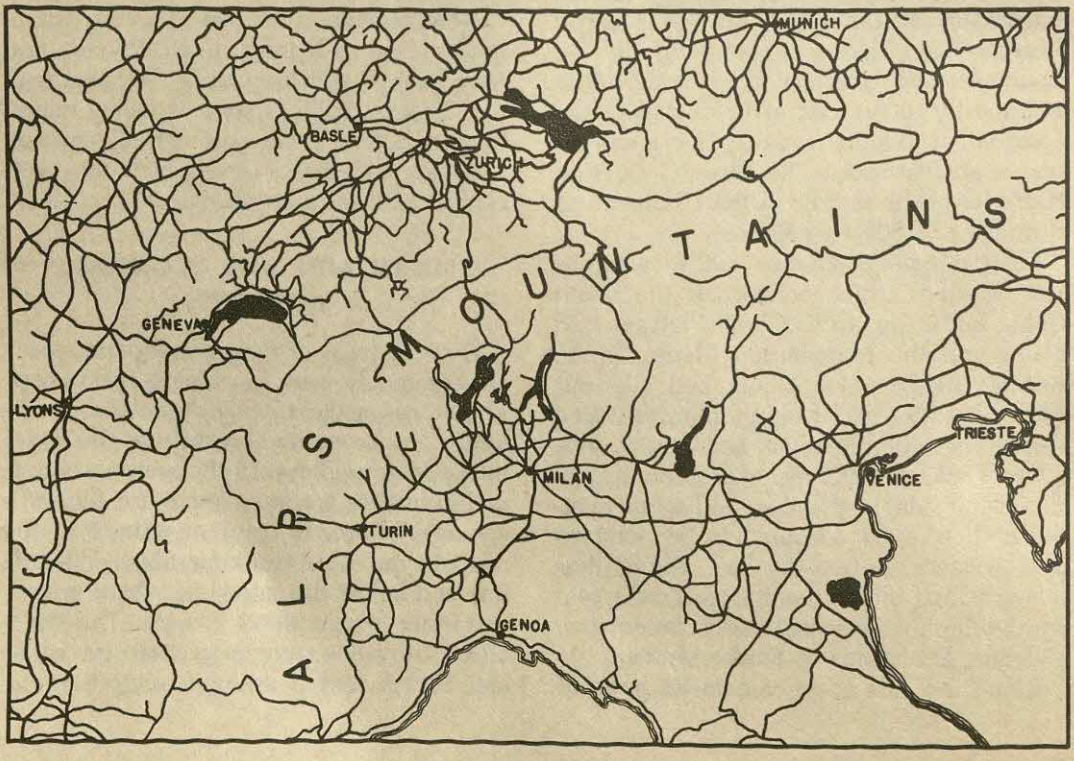
Mining is another common occupation in mountains. Mountain areas often consist partly of igneous and metamorphic rocks which may be rich in ores of copper, gold, silver, lead, zinc, and other metals. In the United States mining is the principal pursuit in many sections of the Rocky Mountains.

Possibly the principal economic role of mountains is of a negative character. Mountains form not only climatic barriers, but also barriers to transportation, and thus to commercial intercourse. For centuries China was practically isolated from the Western world by the mountain masses of interior Asia. In America the Appalachians were long a barrier which hindered the westward expansion of the early colonists.

Transportation across mountain regions necessarily utilizes the relatively low passages over the crests, known as *passes,* which usually are comparatively few in number. (See Fig. 42.) Construction of roads or railroads over passes is often difficult, and the higher passes are frequently blocked by heavy snow during the winter season. With the advance of technical knowledge, man has learned to build better roads and to pierce mountain ranges by means of tunnels, some of which are many miles long. Not only initial expenditures for such modern routes of transportation are much higher than in plains or hill country, but cost of maintenance is higher, as is that of power needed to overcome the steep grades. All this must be paid for, one way or other, and it is usually by higher rates for the transportation of passengers and goods. Thus mountains remain economic obstacles.

Mountains, as a result of their height, often receive large amounts of precipitation in the form either of snow or of rain,

Fig. 42. Railroad network in the Alps and adjacent regions. Barrier effect of high mountains shows clearly.



and this moisture may be indispensable to the plains below them. The cotton raising of Russian Turkestan depends upon the snows of the Tien Shan and Hindu Kush mountains for irrigation water, just as the fruit and rice production of the Valley of California depends upon Sierra Nevada snows. The height of the mountains also results in a coolness that makes them a refreshing summer retreat for people from hot lowlands. In addition, the steeply descending rivers are suitable for generating hydroelectric power.

THE PLAINS OF THE WORLD

Fortunately for man's economic pursuits, about 33 per cent of the world's land consists of comparatively low areas, with altitudes of less than 660 feet (200 meters). About 40 per cent of the land area lies at elevations of less than 3,300 feet, and 27 per cent at elevations of about 3,300 feet (Fig. 43). The 40 per cent includes quite a bit of hilly land and some lands with much more relief, but a fair proportion of it could be called plains. In most respects, plains have the most favorable conditions for plant and animal life as well as human occupance. They contain the least stony and the most productive soils, while lack of great relief or steep slopes insures relative safety from erosion of the soil material. Road and railroad transportation encounter no major obstacles aside from water bodies, and many rivers are navigable.

It is no accident that by far the greatest percentage of the world's population lives in plains areas, as in northwestern Europe, southwestern Russia, central United States, northern India, and parts of China. In the fertile alluvial lowlands of the Ganges and Brahmaputra, the Hwang-ho, and Yangtze Kiang, concentration of population is particularly great. There are, of course, plains that are sparsely settled. For example, those of northern Asia are sparsely populated because of long winters, those of Turkestan because of aridity. Such plains may never be able to support dense populations. In fact, according to a recent estimate, only about 30 per cent of the land surface is sufficiently level, warm, and moist to be considered capable of producing ordinary crops. The plains are the seats of greatest agricultural productivity and greatest industrial progress. On them have been built most of the cities of the world and on them are found the principal centers of cultural achievement.

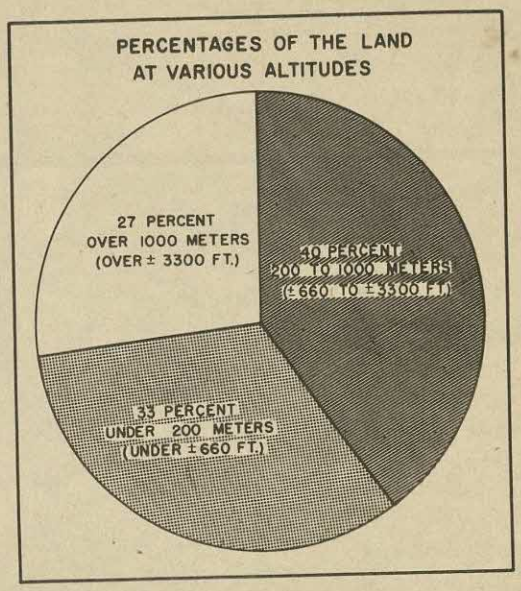


Figure 43.

SELECTED REFERENCES

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5

Factors Responsible for Climatic Differences

"EVERYONE TALKS about the weather but nobody does anything about it." The oft-quoted statement by Mark Twain concisely expresses the interest that most of us who live in the middle latitudes have in the daily weather. This widespread interest, so general as to be taken for granted, is obviously due to the sudden changes that are characteristic of our weather and the bearing that those changes have upon our daily activities. But our interest often is more profound than is indicated by the trifling remarks we may make concerning the weather of today or tomorrow. When planning visits to other states or countries or when contemplating a change of residence, we are likely first to inquire how cold the winters are and how warm the summers, whether it rains much or little, whether sunshine or cloudiness prevails. In other words, we seek to inform ourselves concerning the climate of our new place of abode.

WEATHER AND CLIMATE

Whereas the study of the weather—meteorology—deals with the actual atmospheric conditions that prevail at any given time, the study of climate—climatology—deals with the averages of known weather conditions characteristic of a given area, as well as with the frequency of significant deviations from those averages. Thus the climate of a locality can be studied adequately only if records of its elements—such as temperature, precipitation, wind direction, wind strength, and so on—are available for many years. Long-time records are especially necessary in the middle latitudes, where not only the changes in the weather from day to day may be great, but where there is considerable variation from year to year—mild winters and severe winters, hot summers and cool summers, occurring in irregular alternation and succession. In such regions, climate, as the average weather, often seems at first to be a somewhat illusory concept, and deviations from the averages may become at least as important as the averages themselves. In regions of dry climate the variability of precipitation from year to year may be even more important

climatically than the average annual total.

In large parts of the world, however, atmospheric conditions are not so changeable, and the principal characteristics of the daily weather may be foretold fairly accurately by reference to the calendar. It may be either always warm or always cold, always rainy or always dry, or wet and dry seasons may alternate with a considerable measure of regularity. Uniformity of daily weather is especially characteristic of the lower latitudes. Under such conditions the weather generally is not the absorbing topic of conversation that it is with us, and records covering only a few years may suffice to give a fairly accurate idea of the climate. However, even in these areas conditions vary somewhat from year to year. There are likely to be differences in the intensity and the length of the dry and the rainy seasons as well as shifts in the beginning and the end of these seasons.

In order to forecast the weather in the middle latitudes with some degree of accuracy, it is necessary to have available basic observations on temperature, atmospheric pressure, humidity, and other weather elements for many places and over areas of considerable extent. While formerly weather forecasting was of importance primarily to shipping and agriculture, the development of a network of airlines has greatly increased the need for basic weather observations, made not only at the surface but also aloft, so as to foresee flying conditions and reroute planes whenever necessary. In turn, the airplane, the pilot balloon, and the radiosonde have furnished increasing quantities of observations at higher levels of the atmosphere, and these are indispensable for forecasting surface weather with greater accuracy.

In recent decades the number of meteorological stations in the world has increased greatly, not only in the middle latitudes but also in the tropics. This increase in the number of available records has resulted in a better understanding of the climate of many parts of the world. Density of meteorological networks is, however, still very uneven. The United States, with adjacent portions of Canada, and the continent of Europe, with some adjacent areas, have the densest networks. In parts of South America, such as the Amazon region, in parts of Africa, the Near East, interior Asia, and the polar regions, stations are widely spaced, and records often are brief and discontinuous. Thus our climatic information on different parts of the world is not equally reliable and complete.

Behind the complicated differences between climatic conditions in various parts of the world lie some simple factors which govern the major traits of the distribution of heat, barometric pressure, and airflow over the earth. These factors are: (1) the sphericity of the earth, (2) the inclination of the earth's axis and its parallelism during the revolution of the earth around the sun, and (3) the rotation of the earth.

The major traits of the distribution of heat, pressure, and airflow are modified by such other factors as distribution of land and water masses, occurrence of warm and cold ocean currents, major relief features, particularly high, long, unbroken mountain ranges or extensive high plateaus, and the occurrence of so-called cold fronts and warm fronts. The result of the interaction of all these factors is a highly complex climatic pattern, which is represented in simplified form in the map, Climatic Regions of the World, at the end of the book.

MAJOR FACTORS AFFECTING WEATHER AND CLIMATE

Radiation and insolation. The sun sends out into space huge amounts of radiant energy, of which a very small fraction reaches the earth. Some of this radiation is visible, constituting light; some energy comes to us as ultraviolet radiation and some as infrared.

Insolation is the rate at which direct solar radiant energy is received on a horizontal surface. The insolation received at any moment on any small surface area of the earth depends upon the angle of the sun's rays and the amount of energy lost while the rays passed through the atmosphere. The total amount of insolation received in the course of a day depends, of course, also on

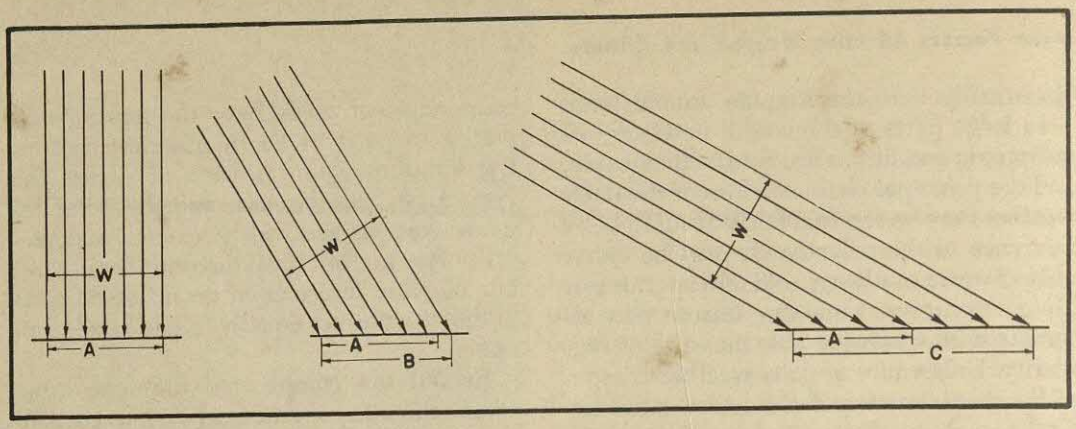


Fig. 44. Diagram of the sun's rays striking the earth vertically and obliquely. Diameters of the bundles of rays (W) are equal. Note that the diameter of the area over which the heat is distributed is greater in B, and considerably greater in C.

the duration of insolation, i.e., the length of the day, and may be modified temporarily by cloudiness.

INSOLATION IN RELATION TO VARYING DISTANCE OF THE EARTH FROM THE SUN. The orbit of the earth's revolution about the sun is an ellipse rather than a true circle, and therefore the distance of the earth from the sun varies during the year. In December the earth is about 3 million miles nearer the sun than in June, but this difference in distance is so slight in comparison with the average distance of the earth from the sun (about 93 million miles) that it has no appreciable effect upon the amount of heat received daily during the year. Thus for ordinary purposes we may neglect differences in distance between the earth and the sun.

INSOLATION IN RELATION TO THE SPHERICITY OF THE EARTH. The great differences in the amount of insolation received annually

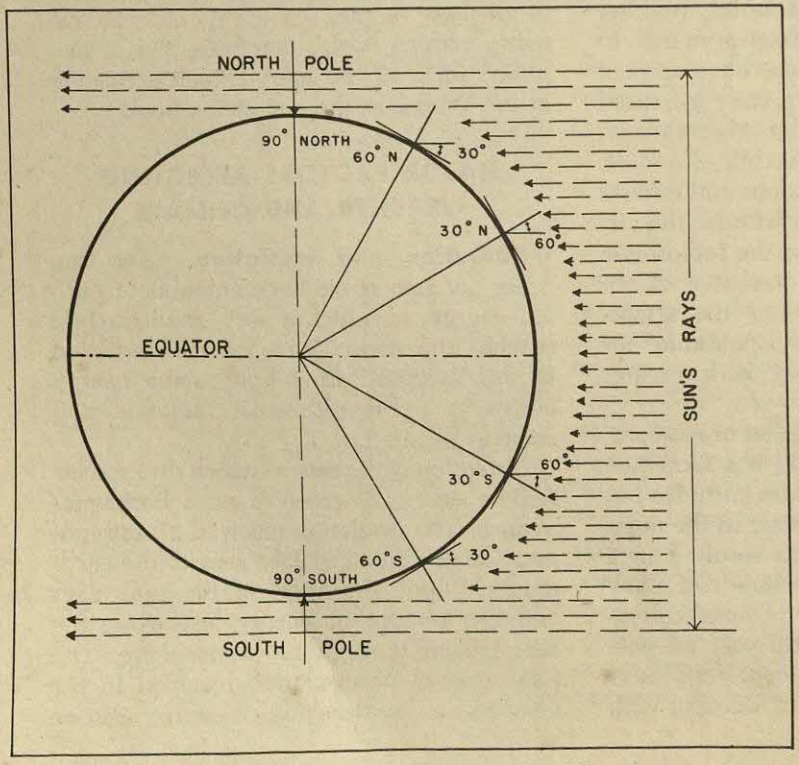


Fig. 45. Diagram of the earth and rays of the sun striking it during the equinoxes. Because of great distance of the sun its rays may be assumed to be parallel. Note the different angles to what is horizontal on the earth at latitudes 30, 60, and at the poles.

at places near the equator and at places remote from it are due to the sphericity of the earth. A bundle of solar rays will illuminate and heat a much smaller area if it shines upon a surface at right angles than if it strikes it obliquely (Fig. 44). If the rays are concentrated upon a smaller area, the intensity of lighting and heating is, of course, much greater than if they are dispersed over a larger area. Thus, the angle at which the rays of the sun strike a portion of the earth's surface is highly significant. Since the diameter of the earth is exceedingly small in comparison with the distance that the rays of the sun must travel, we may, for all intents and purposes, assume that the rays reaching us are parallel.

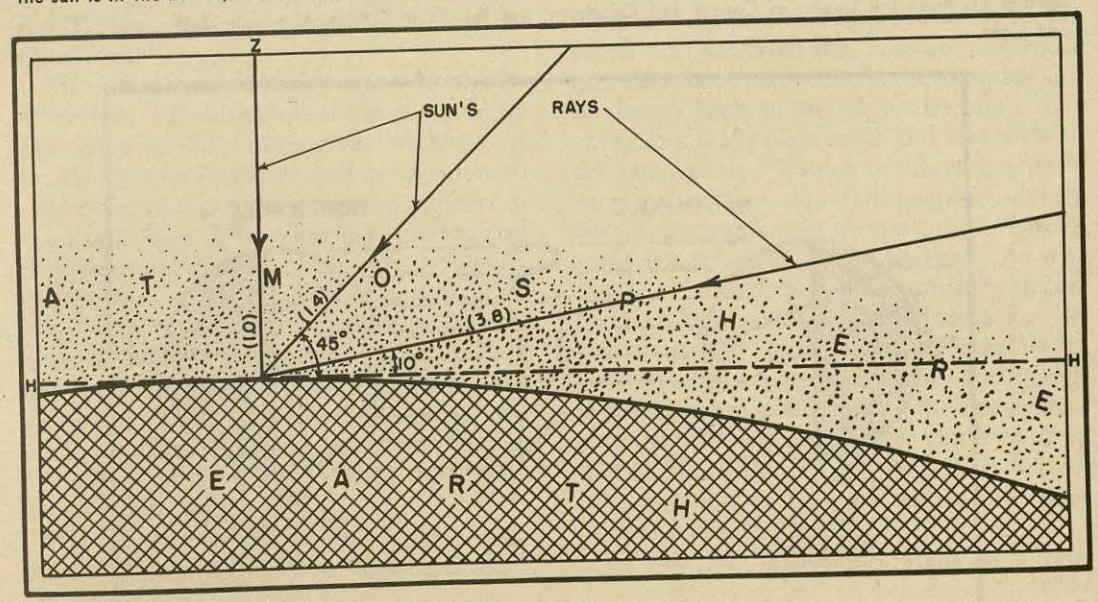
Near the equator the rays shine almost vertically upon the earth at noon, whereas in the higher latitudes the noonday rays strike the surface obliquely (Fig. 45). During the equinoxes, in March and September, the sun's rays strike the equator at an angle of 90°, while they strike the 35th parallel at an angle of 55°, and the 60th parallel at an angle of only 30°.

On their way through the atmosphere the sun's rays lose part of their energy through absorption, dispersal, and reflection. The farther they travel through the atmosphere, the greater is this loss (Fig. 46). It is evident that toward the poles, where the sun's rays cross the atmosphere more and more obliquely, the amount of atmosphere traversed and the loss of radiant energy sustained is much greater than near the equator.

The same phenomenon can also be observed in the course of a day. In the early morning, when the sun stands low in the sky, the sun's rays must traverse a great deal of atmosphere to reach the eye of the observer. At that time the rays have lost so much energy that it is possible to look into the sun. At noon, with the sun much higher in the sky, it is not safe to do so. As a logical result of these differences in the angle of the sun's rays and the lengths of their paths through the atmosphere in low and in high latitudes, average annual temperatures on the earth generally decrease from the equator to the poles.

INCLINATION OF THE AXIS AND PARALLELISM DURING REVOLUTION. The amount of heat each spot on the surface of the earth receives varies during the course of a year. This is a direct result of the fact that the axis of the earth is not at right angles to the

Fig. 46. Differences in length of path through the atmosphere of the rays of the sun, when the sun is in the zenith, and when 45° and 10° above the horizon.



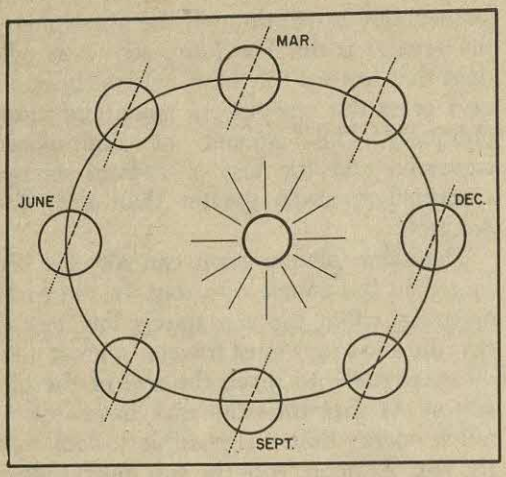


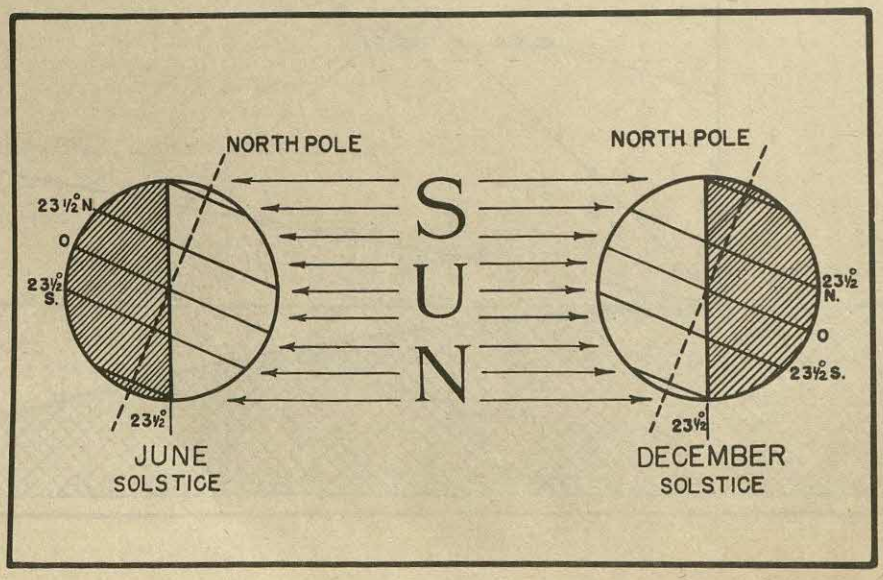
Fig. 47. Parallelism of the earth's axis. In any point of the orbit the axis of the earth is parallel to all of its previous positions.

plane of revolution, but is inclined toward it at an angle of 66½°. Both the inclination and the orientation of the axis are persistently maintained during the entire revolution of the earth around the sun, so that in any position of the earth in its orbit the axis is parallel to all its previous and prospective positions. The North Pole of the earth always points toward the North Star, Polaris. This maintenance of orientation is called *parallelism of the axis* (Fig. 47).

SEASONS. Because of the inclination of the axis of the earth toward the plane of its orbit, the Northern and Southern Hemispheres are alternately the more directly exposed to the sun's rays. On June 22 the position of the axis is such that the Northern Hemisphere is turned toward the sun (Fig. 48). Thus the rays of the sun strike this hemisphere's surface at relatively large angles, up to as much as 90°. The high position of the sun in the sky makes for greater insolation north of the equator, and consequently the season is warm and is termed *summer* by northern people. During this same period the Southern Hemisphere is turned away from the sun, and the solar rays strike it at comparatively small angles. As the sun stands relatively low, the effectiveness of its rays is less, and temperatures are lower. It is the *winter* of the Southern Hemisphere.

SOLSTICES AND EQUINOXES. The inclination of the earth on its axis causes seasonal variations in the apparent positions of the sun in the sky. At noon on June 22 the sun strikes at an angle of 90° in latitude 23½°N. This parallel is named the *Tropic of Cancer*. Conversely, on December 22, the sun is ver-

Fig. 48. Angles at which the sun's rays strike the surface of the earth on June 22 and December 22. Note the Tropics of Cancer and Capricorn, and the Polar Circles. Also note day and night.



tically above the parallel of 23½°S., the *Tropic of Capricorn* (Fig. 48). These two dates are known as the *solstices,* or "points where the sun stands still," because for several days before and after each of these dates there appears to be no change in the apparent position of the sun in the sky at noon. June marks the period of the summer solstice in the Northern Hemisphere and of the winter solstice in the Southern Hemisphere. December, on the other hand, is the period of the winter solstice in the north and of the summer solstice in the south. Twice yearly, about March 21 and September 22, the sun stands vertically over the equator, midway between the two tropics. We speak of these dates as the *equinoxes* because days and nights are then each of 12 hours duration all over the earth.

Only in the area between the two tropics can the sun appear in the zenith. At the equator the sun at noon can never be farther from the zenith than 23½°, while toward the tropics this figure gradually increases to 47°. In higher latitudes the differences in the angles of the sun's rays are much more significant. At 50°N., for example, the maximum angle above the horizon in June is 63½°, and the minimum angle in December, 16½°. By referring to Figs. 44 and 46 it will be clear that the effects of these different angles in the middle and higher latitudes are much greater than in the region between the Tropic of Cancer and the Tropic of Capricorn.

The effects of rotation upon heat distribution. The rotation of the earth on its axis once in 24 hours gives within that period heat and light as well as darkness to most parts of its surface. The sun appears to rise in the east, to travel across the sky, and then to set in the west. Actually, however, the earth is turning in the opposite direction, from west to east. Deception in such matters is often experienced. Who has not had the sensation of moving while seated in a railroad carriage in a station, only to discover a little later that the train on the next track was slowly pulling out of the station in the opposite direction?

The change from day to night causes fluctuations in temperature. During the day insolation ordinarily raises the temperature about us. At night part of the heat accumulated during the daytime is given off, radiated into space, and temperatures drop. These daily fluctuations are of considerable importance. They prevent excessive heating. In many parts of the world the nights give some respite from the heat of the daytime. In the spring the daytime temperatures may be favorable for plant growth, but the low temperatures of the early morning often bring with them the danger of frosts.

If the earth rotated on an axis standing vertically to the plane of its orbit, days and nights would always be of equal length. Since the axis is inclined at an angle of 23½°, the respective lengths of day and night vary in the course of the year. In the Northern Hemisphere in June the days are longer than the nights; in December, the reverse holds true (Fig. 48).

Although near the equator the difference between the length of day and night is relatively slight, toward the poles it becomes steadily greater until, beyond the polar circles, there are both a polar day and a polar night of increasing duration.

Thus, differences in the length of day and night accentuate temperature differences due to the seasons. With increasing latitude, summer insolation lasts a longer, and winter insolation a shorter, period.

SEASONAL CHANGES IN HEAT DISTRIBUTION. Near the equator and approximately as far north and south as the Tropics of Cancer and Capricorn respectively, the noonday sun is always high in the sky. The sun's rays strike at a fairly high angle and lose little to the atmosphere. Besides, the days are never as short as they are farther poleward in winter. Consequently, this part of the earth's surface is relatively warm all year. The seasons are characterized not so much by differences in temperature as by fluctuations in rainfall during the course of the year. Vegetative growth never entirely ceases, although in some sections of this zone the occurrence of an annual dry season may cause most of the trees and shrubs to shed their leaves, thus creating a landscape similar in some aspects to that of the northern winter.

In the middle latitudes there is a pro-

nounced temperature contrast between the period during which the noon sun stands high and that during which it stands low in the sky. In these regions we have a true summer and a true winter. The summer is the growing season, and the winter is the season during which the entire vegetation is inactive for lack of sufficient heat. Near the poles the temperatures are so low even in the warmer half of the year that plant growth is impossible. These are the areas of perpetual ice and snow.

IF THE AXIS WERE NOT INCLINED. Were the earth's axis not inclined, there would be no seasons, and the world would be markedly different from the one we inhabit. The warm belt would be a narrow band of excessive heat gradually merging into cooler areas to the north and south. There would be no regions with alternating summers and winters. The frozen wastes about the poles would extend farther equatorward than they do now. Days and nights would be of equal length everywhere. At any given place the daily insolation would remain unchanged throughout the year. It is difficult to visualize such a world, one of unending climatic monotony in contrast to the stimulating diversity which is our present condition.

ELEMENTS OF WEATHER AND CLIMATE

The elements of the weather, which are studied separately and in combination for purposes of weather forecasting, are: (1) temperature, (2) air or barometric pressure, (3) wind direction and wind velocity, (4) humidity, (5) cloudiness and sunshine, (6) precipitation, and a few others.

For the basic quantitative description of climatic conditions, as has been mentioned before, we must depend largely upon meteorological data gathered primarily for purposes of weather forecasting (Fig. 49). Instead of using observations for one day or hour, average values are calculated on the basis of observations which may run over many years—10, 20, and preferably more than 25 years. It is clear that a tremendous amount of calculating is involved for each station used. Fortunately, modern calculating machines and punch-card methods have proved a great aid in the use of available basic statistics.

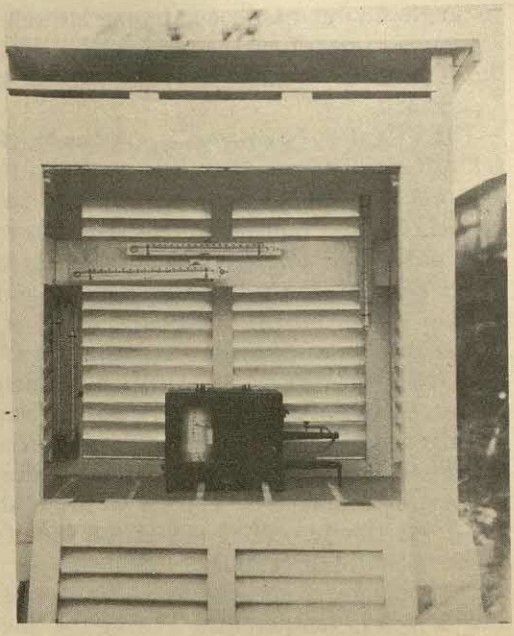
The elements of greatest interest for climatic study are somewhat different from those of prime importance for the study of the weather. Also, in many cases the phases of the elements concerned are different.

For example, in the study of climate barometric pressure is of subordinate importance, while in meteorology it is of prime importance. One reason is that men, plants, and animals do not seem to be greatly affected by ordinary differences in pressure, but changes in barometric pressure are major indicators of impending weather changes.

While temperatures are important to both, temperatures of the upper atmosphere are not as important in climatology as they are to weather forecasting. Similarly, insofar as humidity is concerned, vapor pressure and specific humidity are important to the mete-

Fig. 49. Instrument shelter at a U.S. Weather Station. The black box contains a thermograph, or self-registering thermometer. Other thermometers can be seen above. To the left is a sling psychrometer for the determination of relative humidity.

Courtesy U.S. Weather Bureau



orologist, whereas relative humidity and evaporation are of great direct interest to the student of climatology.

Precipitation looms large as a climatic element because of its great importance for agriculture and other activities of man, while the meteorologist may be more interested in cloudiness as it affects air travel.

Temperature, air or barometric pressure and winds, humidity, and precipitation will be discussed in this chapter because they are considered to be the most important elements.

Temperature. Temperature is the term used to express the intensity or degree of heat. It is measured by means of a thermometer or thermograph. Energy is radiated into space by the sun, and although the earth intercepts but a very small fraction of the total, this fraction is the source of practically all the heat energy available upon the earth. Of the radiation that reaches the surface of the earth, part is reflected back and part is absorbed by the surface. The amount reflected usually is small—less than 10 per cent—but it may be high in the case of snow-covered surfaces, such as the Antarctic continent or the frozen Arctic Ocean. Part of the radiant energy absorbed by the surface of the earth is changed into heat, which is transferred by radiation and conduction to the air immediately above. Thus the atmosphere is heated primarily from below, which explains why it becomes cooler as one goes up in an airplane.

The temperature of the air always lags somewhat behind that of the earth. Neither does the air heat up as much during the day or cool off as much during the night as does the earth. Maximum air temperatures do not occur at noon but rather in the afternoon, while minimum temperatures ordinarily occur in the early morning hours rather than around midnight. What is true in the course of a day is also true in the course of a year. The lowest winter temperatures occur after the winter solstice, in January, or even February, and the highest summer temperatures usually occur not in June, but in July and August.

The difference between the highest and the lowest temperatures during 24 hours is called the daily or diurnal range, while the difference between the average temperatures of the warmest and that of the coldest month is called the seasonal range. The amount of seasonal range is an important climatic criterion.

DISTRIBUTION OF HEAT ON THE EARTH WITHOUT CIRCULATION. If the atmosphere were completely at rest and if, in addition, land masses and water bodies were equally distributed, temperatures would be as given below for each of the latitudes listed:

Latitude	0	10	20	30	40	50	60	70	80	90
Temperature, degrees F.	91	89	83	72	57	37	12	−11	−26	−31
Actually observed temperatures	79	80	78	69	57	42	30	14	2	?

As can be seen from the observed averages, actual conditions correspond closely only in about latitude 40°; from here to the equator observed values are lower, and in the higher latitudes they considerably exceed the theoretical values. This is due to the following facts: (1) the atmosphere is not at rest, that is, there exists a general air circulation by which heat is transferred, and (2) land and water masses are not evenly distributed.

THE EFFECTS OF UNEQUAL HEATING OF LAND AND WATER. The effects of the sun's rays on land and water are not the same. Equal insolation results in the temperature of water rising less than that of the land. This is due to three major factors: (1) the relatively high specific heat of water, that is, more calories of heat are necessary to raise by one degree the temperature of water than of land; (2) the transparency of water allows the sun's rays to penetrate to a much greater depth than on land, and thus the intensity of heating at the surface is less; and (3) the mobility of water permits transference of heat to colder layers or colder areas by means of waves, turbulence, and currents.

As a result of all these factors, water bodies remain at much steadier temperatures than do land areas. In the middle latitudes the land is much warmer than the ocean during the summer; it is also much colder in winter. We are all familiar with this phenomenon. In June the air in the

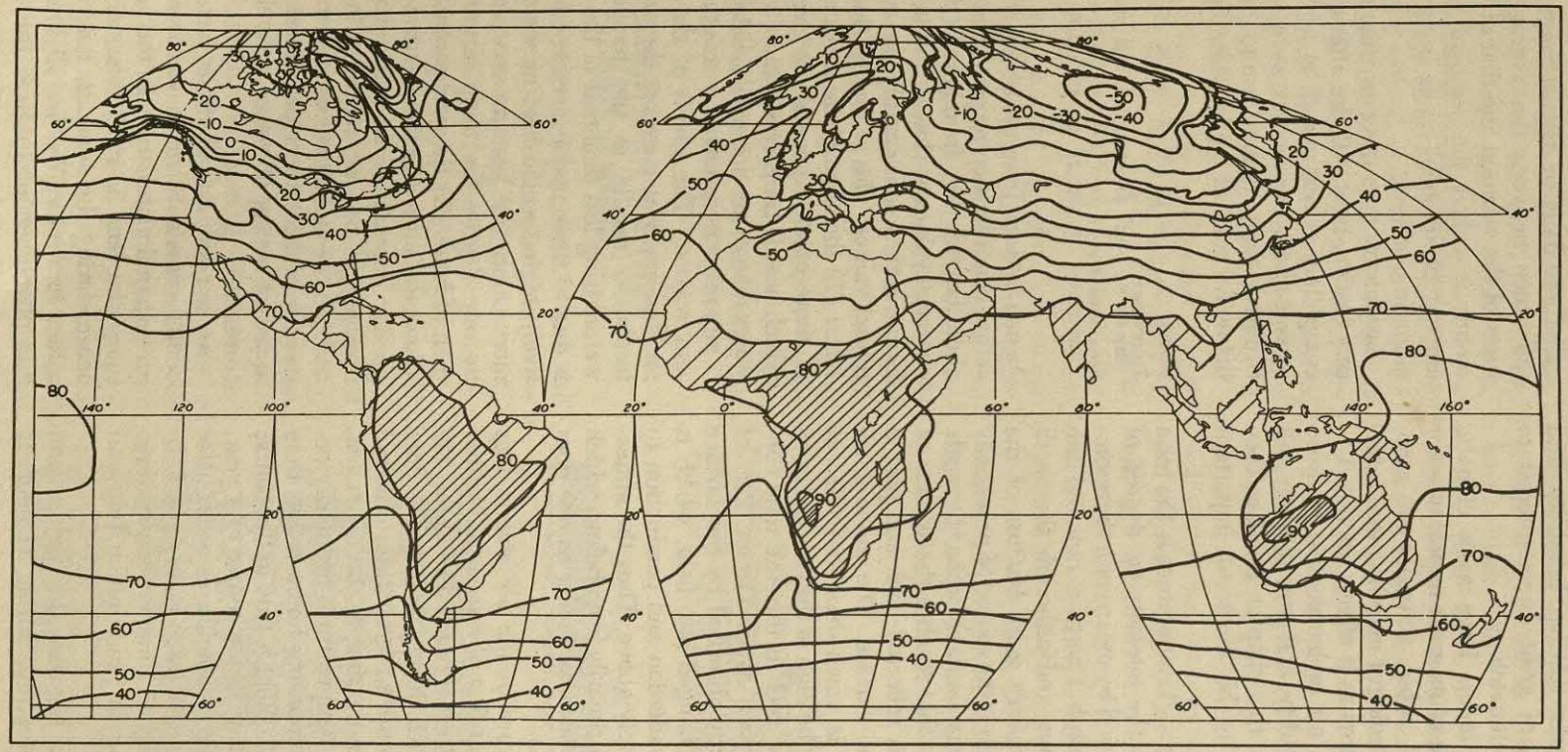


Fig. 50. Isothermal lines for January. Degrees Fahrenheit. Cross-hatched sections are land areas with average January temperatures of 70°-80°F., 80°-90°F., and over 90°F.

middle latitudes may feel balmy, but the water of a lake, river, or "the old swimming hole" may feel disagreeably cold; while in the fall swimming may be pleasant as long as one remains well submerged. This difference in land and water temperatures is of great climatological importance, especially in winter. Extensive water bodies moderate the temperatures of nearby land areas when the winds are blowing toward the land. The air masses that come from over the oceans are comparatively cool, although moist, in summer. In winter they bring higher temperatures to the land, though at that time of the year the air that thus comes in from over the ocean may feel damp and raw.

OCEAN CURRENTS. Other modifications in the general distribution of heat over the world are caused by warm and cool ocean currents. Such currents, moving toward cooler or warmer areas, will affect the air masses which move over them, and these, in turn, may affect adjacent land masses. The relatively warmer water of the Gulf Stream, for example, coupled with winds from the ocean, brings ice-free winter conditions to the ports of Western Europe, even those beyond the northern tip of Norway, whereas in the same latitudes in North America the surface of the sea is frozen and marine traffic is at a standstill. (See Fig. 198, p. 312.)

INFLUENCE OF ALTITUDE. Differences in altitude also lead to differences in temperature. At the higher altitudes insolation results in less heating because of the greater loss of heat by radiation through the rarefied atmosphere. Thus, mountain and plateau regions always have lower average temperatures than have neighboring lowland areas.

WORLD DISTRIBUTION OF HEAT. Distribution of temperatures is shown most graphically on maps, not by means of a multitude of temperature figures scattered over the map, but by means of lines connecting points with equal temperatures. Such lines are called *isotherms*. An isothermal map of the world based upon actual average annual temperatures clearly shows the disturbing effects of the factors mentioned above. The isotherms do not follow the parallels around the globe, as one might expect; they bend northward and southward (Figs. 50 and 51). The irregular courses of the isotherms are due to: (1) the unequal distribution of land and water and the resulting unequal heating; (2) the movement southward of large masses of cold air and the movement northward of large masses of warm air; (3) the transference of equatorial heat poleward and of polar cold equatorward by means of ocean currents; and (4) the occurrence of highland areas, where temperatures are lower.

TEMPERATURE AS A CLIMATIC ELEMENT. From a climatic point of view, average monthly and average annual temperatures are most important. Usually averages for January and July are taken as most characteristic. For certain purposes average maximum and minimum temperatures, or even absolute maxima and minima, may be needed. As has already been stated, the seasonal range of temperature is important climatologically, as it indicates the degree to which the climate is influenced by land masses or water bodies—in other words, the degree of continentality or oceanity. Data on the average occurrence of the first and the last killing frost are useful in connection with crop production, as are data on the average length of the frost-free season and the fluctuations in the length of this season.

The changeable temperatures of the middle latitudes furnish an inexhaustible subject of conversation because of their direct relationship to our pursuits and pleasures. But more than that is involved. Changeableness of temperature, and of weather conditions in general, seems to have an energizing influence. The enervating effect of the monotonously warm and humid weather of the rainy tropics is well known. There, hustling white men from cooler climes gradually and almost inevitably become slow-moving, since in the long run the climate is not conducive to such activity as is possible in the middle latitudes. Unfortunately, comparatively little is accurately known as yet about the effects of weather and climate upon the physiology of man and upon his behavior patterns.

Air or barometric pressure and winds. The atmospheric air, obeying the laws of

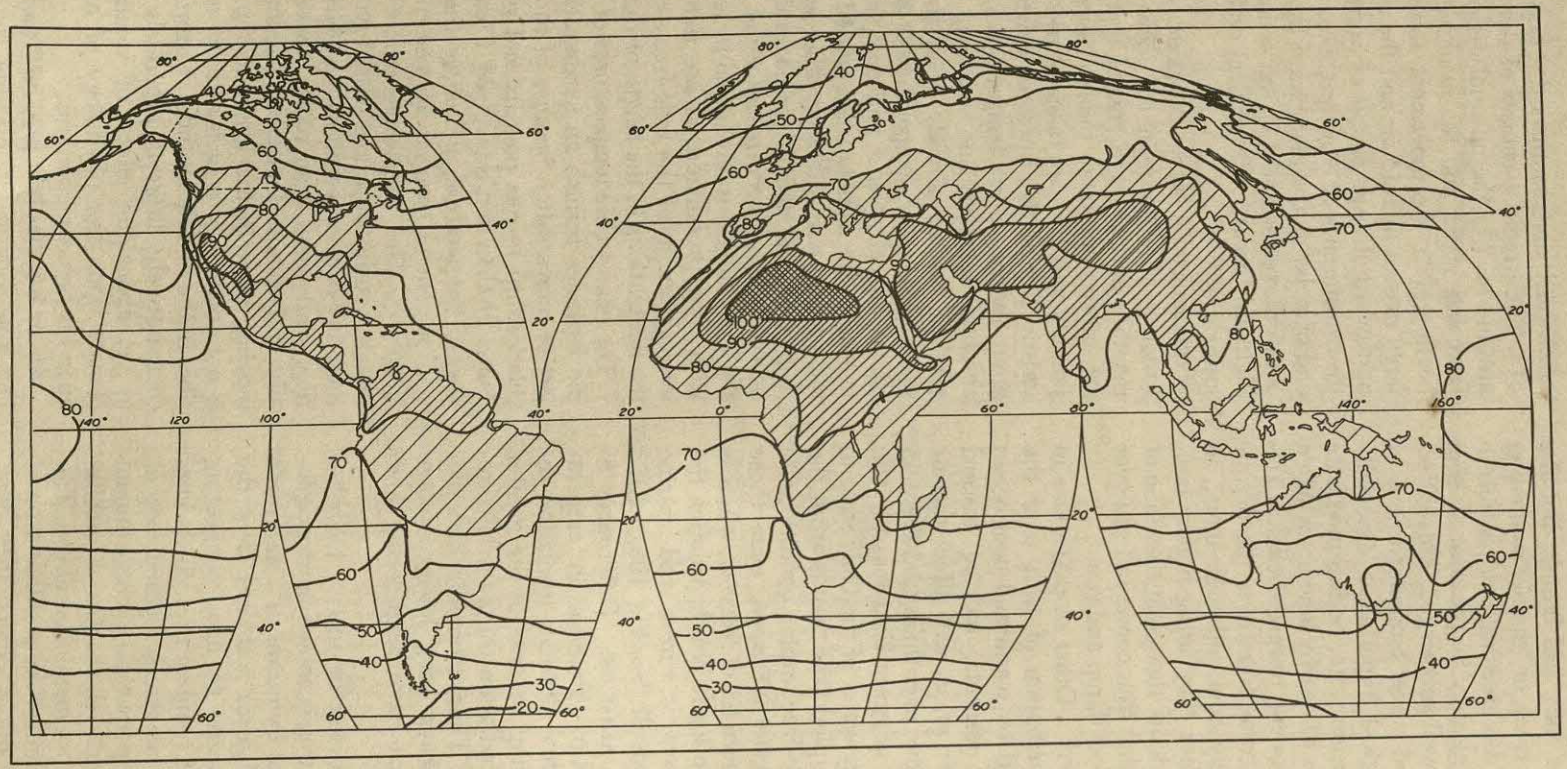


Fig. 51. Isothermal lines for July. Degrees Fahrenheit. Cross-hatched sections are land areas with average July temperatures of 70°-80°F., 80°-90°F., and over 90°F.

gases, exerts pressure in all directions, the amount of pressure varying with the density of the air. At sea level, where the air is weighted down by all the air above it, density is greatest, and the pressure amounts on the average to 14.7 pounds per square inch. At greater altitudes, where the air is not so dense, pressure is less. Air pressure is measured by means of the barometer and the barograph. At sea level the normal atmospheric pressure is indicated by a barometric reading of 29.92 inches, or 760 millimeters; that is, the atmospheric pressure is sufficient to balance a column of mercury about 30 inches high. Another unit of measurement is the millibar (mb). A pressure of 1,013.2 mb is the normal. As the altitude increases, the height of the column of mercury that the air pressure can sustain decreases in the beginning at the rate of about one eighth of an inch per 100 feet. The rate decreases at higher altitudes. The accompanying list illustrates the rate of change.

Relation of Air Pressure to Altitude

Altitude	*Barometer*
–73 feet	30 inches
863 feet	29 inches
1,824 feet	28 inches
2,814 feet	27 inches
3,824 feet	26 inches
4,886 feet	25 inches
5,974 feet	24 inches

Barometric pressure is important especially for purposes of weather forecasting. For this, pressure observations, not only at the surface but also at higher altitudes in the free atmosphere, are needed.

Pressures greater than the normals mentioned above are called "high" pressures; those less than normal, "low" pressures. Distribution of atmospheric pressure can be shown on maps most adequately by means of lines of equal pressure known as *isobars*. Such isobars appear on all modern weather maps and show clearly the areas of high and low pressure, as well as the transitional regions (Fig. 52).

Air tends to move from areas of higher pressure to those of lower pressure. Generally speaking, the greater the difference in pressure per unit of distance (the pressure gradient), the faster the air will move, that is, the stronger the resulting winds will be. The rotation of the earth, centrifugal force, and friction change the direction of airflow so that movement is not straight from areas of high pressure to areas of low pressure, but along a curving path.

From a climatological point of view barometric pressure in itself is not of major importance, as its effect upon living organisms is not very pronounced. However, pressure conditions are of importance for the study of causal relationships in climatology.

The velocity of the wind is expressed in miles per hour and is measured by a device known as the *anemometer*. When air is at rest relative to surrounding objects, we are scarcely aware of its presence; but when it it in motion we readily recognize its pressure as wind.

The atmosphere as a whole would be relatively calm if it were not for the unequal distribution of insolation over the earth's surface. This unequal heating and certain other factors give rise to differences in pressure, which result in the phenomenon of wind. The winds are named as to the direction from which they blow; thus, if air moves from the north toward the south, it is spoken of as a north wind. The direction from which the winds blow with greatest frequency at a given place is called *the direction of prevailing winds*. In ordinary accounts of wind velocity we are likely to find it referred to in approximate terms, such as calms; light, moderate, or strong winds; and gales or storms. Wind strength can be described more accurately by means of the Beaufort scale, which has 12 numerical divisions, ranging from 1, calm (less than 1 mile per hour), to 12, hurricane (over 75 miles per hour). Climatologically, wind strength is important as it may have strong, direct effects on crops and vegetation and may greatly influence rates of evaporation.

Wind direction is also an important climatological criterion. In some areas winds blow steadily from one prevailing direction during most of the year, as in some parts of the tropics. In other areas prevailing wind directions during summer and winter may

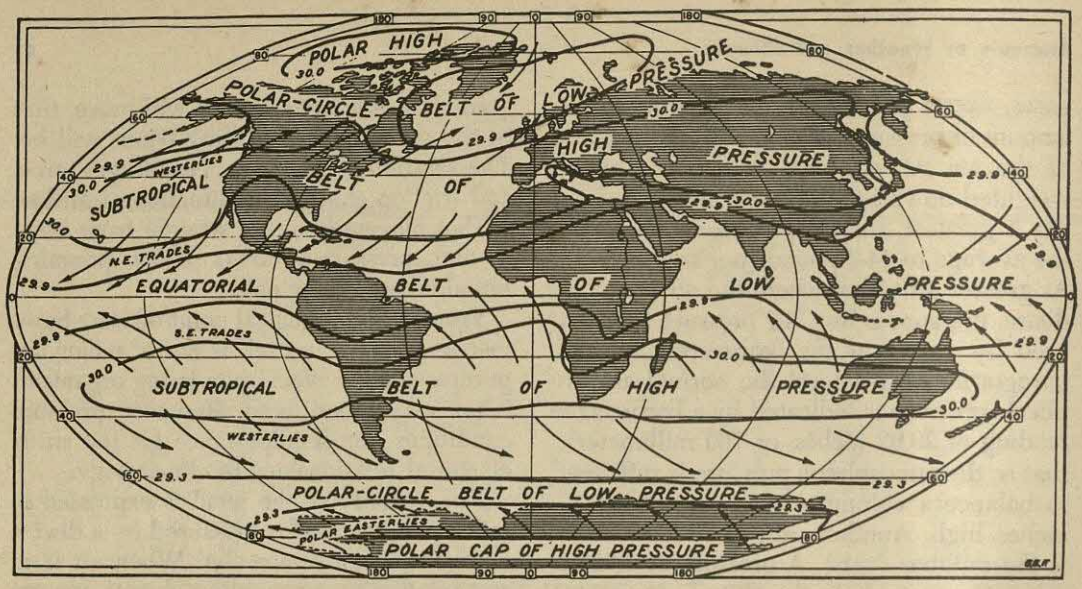


Fig. 52. Average pressure distribution over the earth. The isobars show pressure in inches of mercury.

be roughly opposite, as in the monsoon countries. In the middle latitudes, the so-called areas of the prevailing westerly winds, the most important characteristic of the climate insofar as wind is concerned is the fact that the wind may come from any point of the compass, although westerly directions are most common. Thus when we use the term "prevailing westerlies" the accent should be on "prevailing," rather than on "westerlies."

THE GENERAL CIRCULATION. The average general distribution of air movement in the atmosphere is referred to as the *general circulation*. On the basis of the average distribution of winds, the earth may be divided into a few large zones or *wind belts*. This system of wind belts is represented in highly schematic form in Fig. 53. It must, of course, be understood that in reality the lines between the belts are neither sharp, nor straight, nor stable.

Since annual insolation is greatest near the equator, a belt of slightly below average pressure (29.9 to 29.8 inches) encircles the earth there; this belt is known as the *equatorial belt of low pressure*, or the *doldrums*. The term doldrums is applied most generally to the equatorial calms over the oceans, but lack of any better term seems to make it applicable to the corresponding belt of calms and variable winds over the lands as well. The best varies in width, and in places may even temporarily be absent. Part of the belt lies north of the equator, in southwestern Asia. Due to the persistent heating, ascending air movements are prevalent. Thus, the doldrums are characterized by light, baffling breezes, interspersed with prolonged calms.

On the poleward sides of the Tropic of Cancer and the Tropic of Capricorn lie two belts where the atmospheric pressure remains relatively high all year through (from 30.0 to over 30.1 inches). These are the so-called *subtropical highs* (horse latitudes), which are most persistent over the oceans. Two of these high-pressure areas are permanent in the Northern Hemisphere: one in the North Atlantic, approximately at the latitude of the Azores, the other in the North Pacific. The Azores High and the North Pacific High are strongest in summer and weakest in winter. The other three permanent subtropical highs are located respectively over the southeast Pacific, the southern Indian Ocean, and the South Atlantic. In these regions, as in the doldrums, calms are frequent.

Along the surface, that is, to altitudes of 10,000 to 30,000 feet, winds blow from the subtropical high pressure belts toward the equatorial belt of low pressure. These winds, blowing from the northeast in the Northern

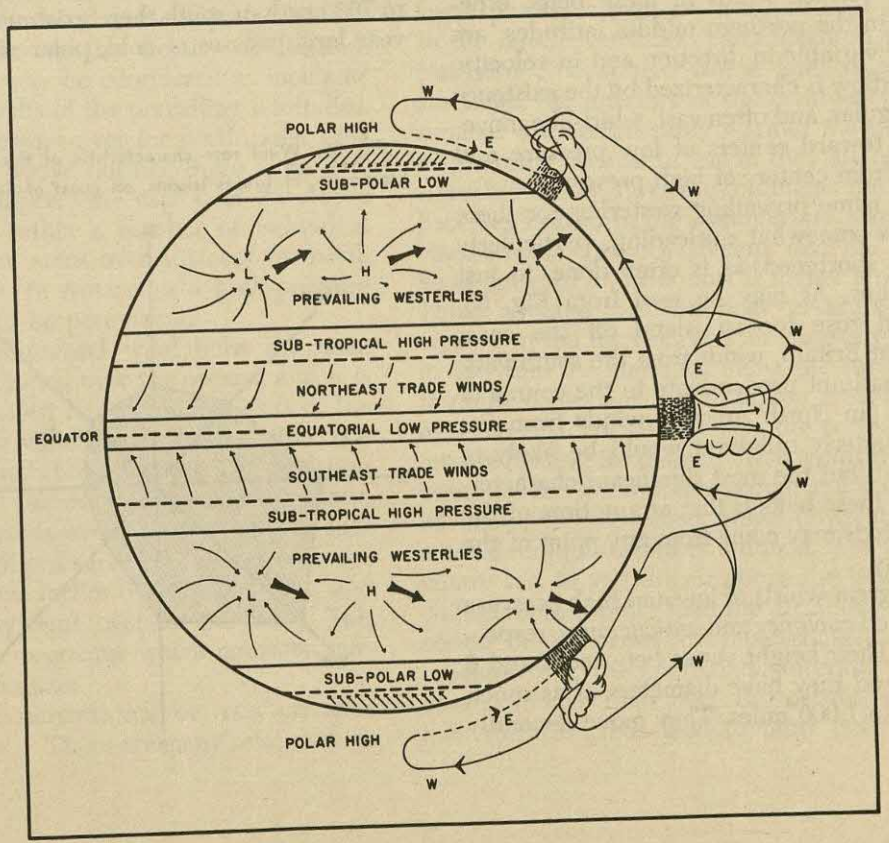
Hemisphere and from the southeast in the Southern, are called *trade winds*. Their velocities vary from moderate to brisk, and their direction, particularly over the oceans, may remain unchanged for weeks at a time. A typical wind rose for a trade-wind area is given in Fig. 54, which shows, for an island in the southeast trade winds, that wind directions are almost exclusively from southeast to east.[1] In the Dominican Republic, located in the northeast trades, wind directions may be largely from the northeast or east, on the south coast even from the southeast. Thus it should not be thought that the northeast trade winds are always and everywhere exactly from the northeast; the same holds true for the southeast trade winds.

At higher altitudes there is a movement of air from the Equatorial Low-Pressure Belt to the horse latitudes. These are the so-called *anti-trades*, which have a strong westerly component. Sometimes, when the Equatorial Low-Pressure Belt is narrow, weak, or even temporarily absent, the trade-wind systems from both hemispheres may meet in the equatorial region. A surface of discontinuity forms in that case, along which strong rain squalls may occur. This is called the *equatorial*, or *intertropical* front.

Poleward, beyond the subtropical highs, lie the belts of the prevailing westerlies. They are best developed in the Southern Hemisphere, where air movements have free play, because of the absence of large

[1] A "wind rose" is a diagrammatic representation of average wind directions in one place. The distance set off on each of the directional lines shows the relative frequency of that wind direction.

Fig. 53. Diagram of the wind belts of the world. The belts of the prevailing westerlies are represented schematically by moving lows and highs, the heavy arrow indicating only a predominant trend of direction of movement. In actuality, of course, the lines between the different pressure belts are far from straight.



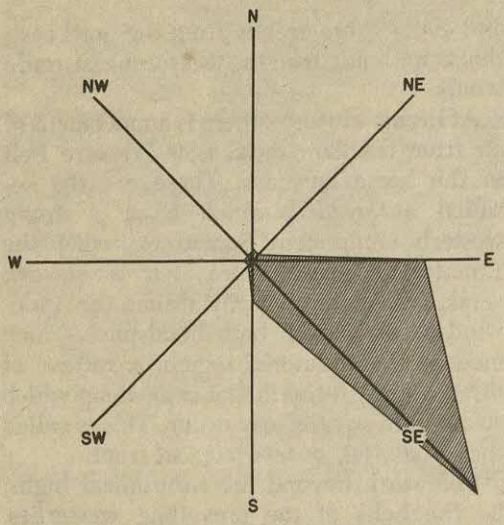


Fig. 54. Wind rose characteristic of the trade winds. Fernando de Noronha Island, northeast of Recife, Brazil.

land masses. In the Northern Hemisphere the presence of the North American and Eurasian continents causes many modifications in airflow.

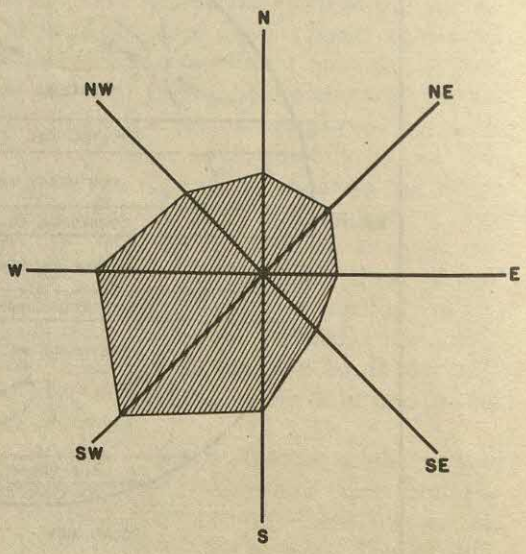
The surface winds in these belts, especially in the northern middle latitudes, are highly variable in direction and in velocity, and airflow is characterized by the existence of irregular, and often vast, whirl-like movements toward centers of low pressure and away from centers of high pressure.

The name prevailing westerlies for these belts is somewhat misleading, particularly if it is shortened, as is often done, to just westerlies. As may be seen from Fig. 55, a wind rose for an island off the coast of Great Britain, winds from the southwesterly quadrant predominate in the course of a year (in North America winds from the northwesterly quadrant would be likely to prevail), but the most significant characteristic of these belts is that at any time of the year winds may come from any point of the compass.

The great whirls of low and high pressure are called *cyclones* and *anticyclones*, respectively. Their height varies between 2 and 6 miles, and they have diameters of as much as 500 to 1,000 miles. They move generally from west to east, not in straight paths but in curving paths, deviating from a true west-east direction. The cyclones, or "lows," are most pronounced in winter, and at that time they are likely to move most rapidly and go farthest southward. Occasionally a low is observed that makes the entire circuit, from Alaska or the North Pacific, through Canada and the United States, over the North Atlantic, through Europe and northern Asia, and back again to Alaska. Usually, however, they weaken and disappear somewhere along the route. The "highs" are more slow-moving, and sometimes they even seem to be stationary for a while, thus impeding the freer movements of the lows. In the summertime, the lows and highs are neither as pronounced as in the winter, nor do they move so rapidly. Their paths lie, on the average, farther poleward in this season.

The belts of the prevailing westerlies, or the "cyclonic storm belts," are really areas of conflict between relatively warm masses of air emanating from the subtropical highs, and masses of cold air which roll forward from the next belt to the north. Beyond 65° to 70° north or south there exist most of the year large masses of cold, polar air, which

Fig. 55. Wind rose characteristic of the westerlies. Stornoway, Hebrides Islands, off coast of Scotland.



tend to move out of this belt as northeasterly winds in the Northern Hemisphere and southeasterly winds in the Southern Hemisphere. The masses of cold air, being heavier, tend to move under masses of warm, subtropical air coming from the south. Where they meet, a surface of discontinuity is formed, a well-marked and distinct surface of separation between the two air masses which are distinct in temperature, humidity, and other characteristics, called the *polar front*. As a polar front passes over, colder air replaces warmer air at the surface of the earth. The polar front usually is best developed in, or in association with, pronounced cyclones. A rapid advance of the polar front in the winter season may bring low temperatures far toward the subtropics, particularly in North America where there are no mountain barriers between the Canadian north and the Gulf of Mexico.

There is a pronounced belt of low pressure in the Southern Hemisphere between latitudes 60° and 70°. In the Northern Hemisphere there are two areas of average below normal pressure near the polar circle, one in the neighborhood of the Aleutian Islands and the other in the vicinity of Iceland. These lows may be considered as incidents within the belts of the prevailing westerlies.

While pressure over the north polar area tends to be above normal, there is no permanent high-pressure "cap" over the Arctic Ocean, but rather a number of individual high-pressure areas over adjacent far north land masses. In Antarctica a high-pressure cap seems to be permanent.

The pressure and wind belts are most clearly developed over the oceans, and it is therefore easiest to estimate the part of the oceans over which each of the wind systems discussed above prevails. The doldrums exist over 9 per cent of the ocean surface, the trade winds over 31 per cent, the subtropical high pressures over 20 per cent, the prevailing westerlies over 24 per cent, and the polar systems over 10 per cent. This leaves 9 per cent over which monsoon currents predominate.

CLIMATIC IMPORTANCE OF THE GENERAL CIRCULATION. There are many relationships between climate and the general circulation pattern. For example, there are pronounced differences between the Equatorial Low-Pressure Belt and the adjacent trade-wind belts. Within the trade-wind belts it makes a great difference whether the air masses move over level land or sea, or whether they strike mountain regions. In the belts of the prevailing westerlies, owing to prevailing wind directions, there are profound differences between east coasts, which have predominance of land winds, and west coasts, which have predominance of sea winds.

As the wind belts tend to move northward and southward with the sun (there is a certain time lag, however), further climatic complications are introduced. For example, in subtropical latitudes—those between the tropics and the middle latitudes—during the summer season the subtropical highs or trade winds may predominate, while during the winter the prevailing westerlies may control the circulation.

SEASONAL CHANGES IN WIND DIRECTIONS. Warm air is less dense than cold air; hence, areas of warm air are often characterized by lower pressures than are areas of cool air. In the middle latitudes, particularly in the Northern Hemisphere where land masses are large, the interiors of the continents in summer are considerably warmer than the neighboring oceans. In winter they are considerably colder. Over the continents the air becomes heated in the summertime, strong convectional currents develop, and the air flows outward to the oceans at higher levels. Thus, average below-normal pressure is created in the interior, and air masses tend to flow into the continent along the surface from the cooler areas, with higher pressures over the adjacent seas. During the period of intense heating in summer, these winds from ocean to land are well developed; as autumn advances, the movement slows down until a relative equilibrium is attained. Then as winter sets in and the air above the land is chilled more rapidly than the air above the ocean, the processes are reversed. The air pressure over the continental interiors becomes greater than over the oceans, and thus surface winds tend to blow outward

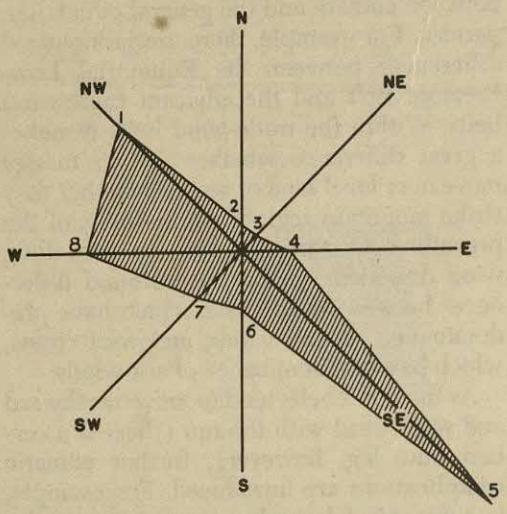
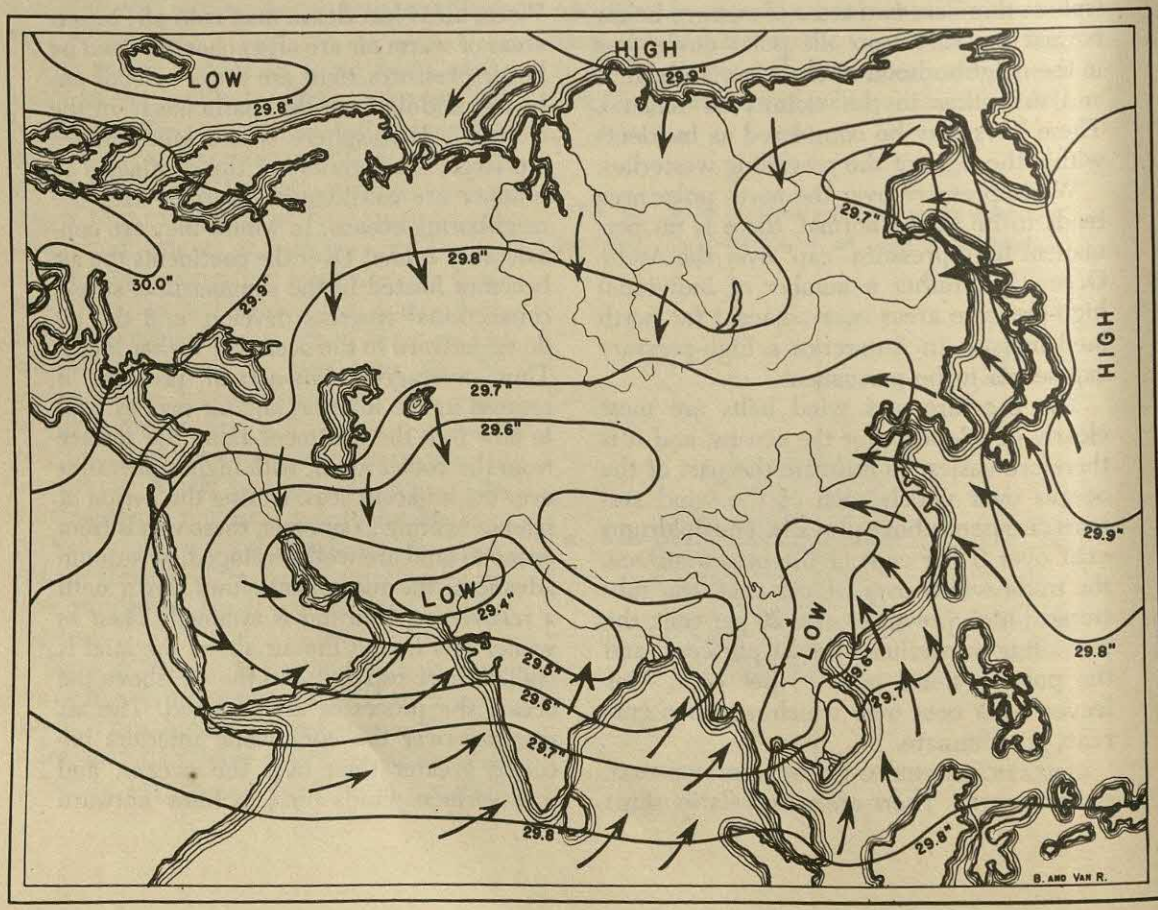


Fig. 56. Wind rose characteristic of the monsoon type of climate. Discovery—East Bank, southeast of Billiton Island, between Sumatra and Borneo.

from the continental high-pressure areas toward low-pressure areas over and adjacent to the oceans. These seasonal wind shifts are known as *monsoons* (Fig. 56). They are best developed in eastern Asia (Figs. 57 and 58), but are also important in the Gulf area of North America and the adjacent plains.

Humidity. Humidity is the moisture associated with the air in the form of *water vapor*, an invisible gas. *Absolute humidity* is the quantity of water vapor present in the air, expressed in the number of grams of water per cubic centimeter, or the number of grains per cubic foot. *Specific humidity* is the relationship between the weight of the water vapor in a unit weight of air and the weight of that air. For climatological purposes relative humidity is more important than either of the above. *Relative humidity* is the ratio between the actual

Fig. 57. Atmospheric pressure and winds in Asia in July.



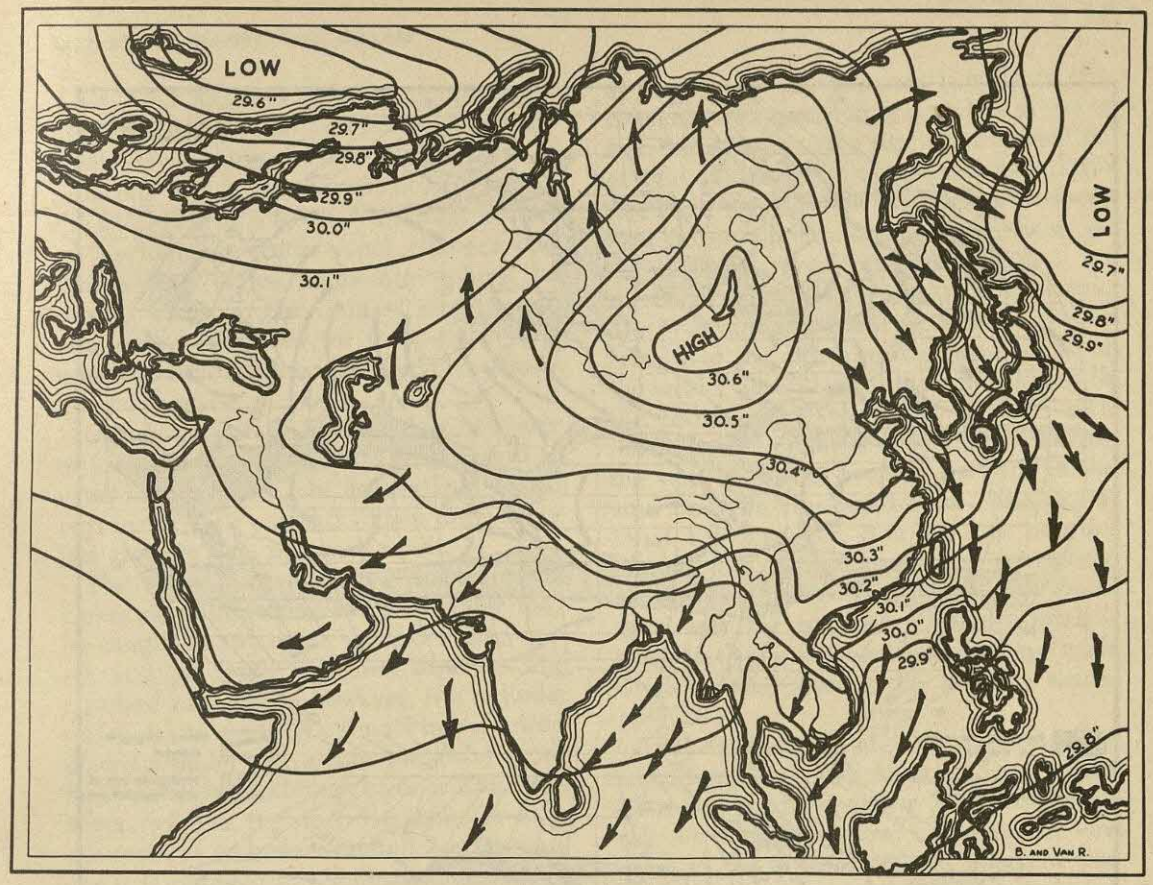


Fig. 58. Atmospheric pressure and winds in Asia in January.

quantity of water vapor in a unit volume of air and the maximum amount that could be held in that space at the same temperature without condensation taking place.

The point of saturation, known as the *dew point,* is reached when a volume of air contains as much water vapor as can exist there without condensation.

Humidity is measured by an instrument known as a *psychrometer* or a *hygrometer.* Records of humidity are usually kept as relative humidity in terms of percentages, as 40, 70, 90, and so on, in each case the saturation point being 100. The capacity of the air for containing water vapor increases with increasing temperature. For this reason while relative humidity is often greater in cold weather than in warm weather, the absolute humidity, or actual weight of water vapor in a given volume of the air, may be less.

Temperature and relative humidity have a close relationship to evaporation. The higher the temperature and the lower the relative humidity, the greater the evaporation. On dry, sunny summer days roads and fields dry up quickly after a rain, while in early spring or winter even small rains give rise to muddy conditions which may last a long time.

Relative humidity is a fairly important climatic criterion not only because of its relationship to evaporation, but also because high relative humidity is sensed easily by the human body. "Muggy" summer days may cause a greater sensation of heat than the thermometer reading would indicate, while "raw" winter days may feel much colder. Unfortunately, climatic data on relative humidity are much more scarce than those on many of the other climatic elements.

Precipitation. The capacity of any given volume of air for retaining water

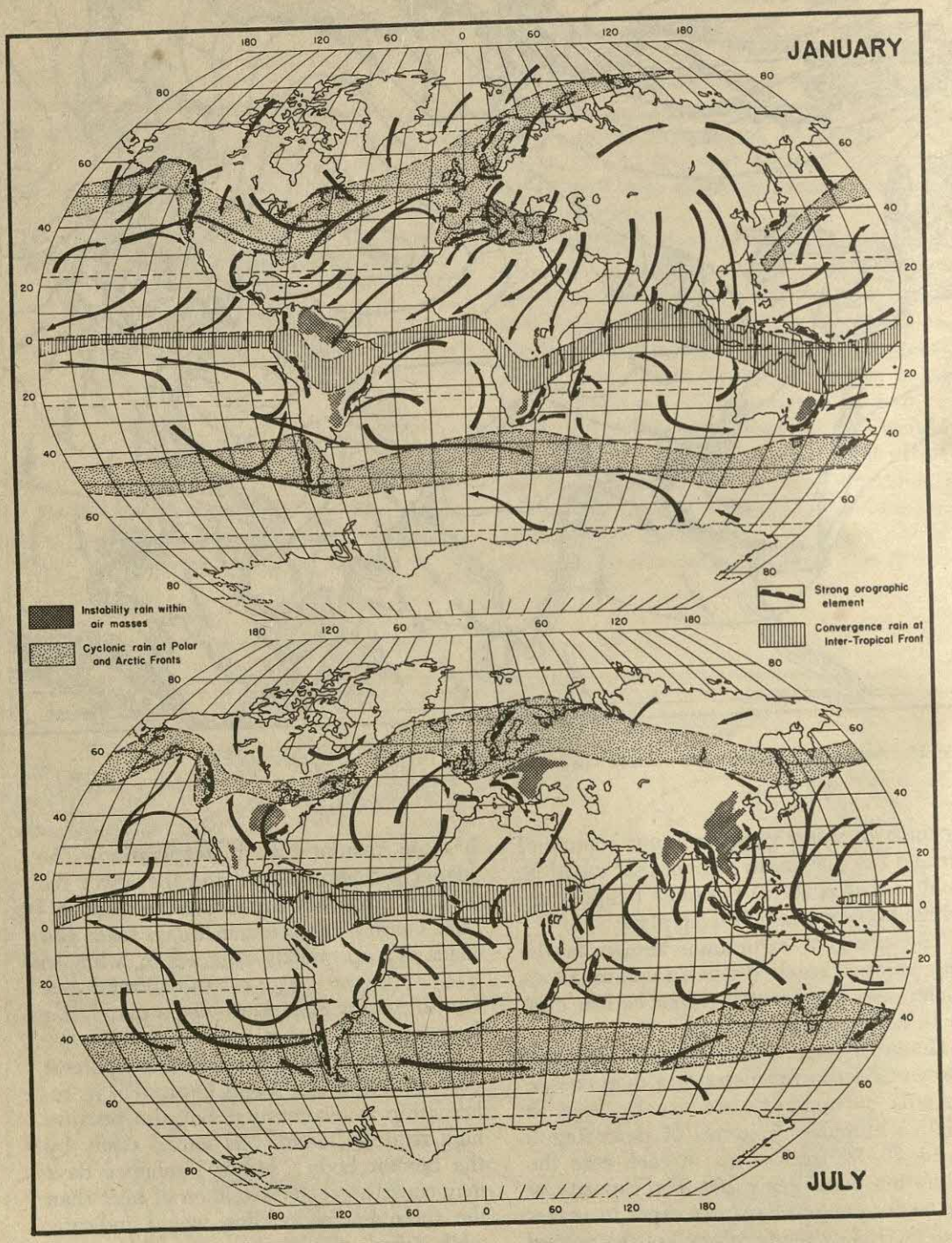


Fig. 59. World distribution of precipitation in January and July. Note the belts of cyclonic rainfall and their displacements, and the belt of tropical rainfall. The arrows represent movements of major air masses. Principal areas of orographic rainfall are also shown. (After A. Austin Miller.)

is largely dependent upon its temperature. Therefore when warm air is cooled, its capacity for holding its moisture content is reduced. When the dew point is reached, the surplus begins to condense; that is, part of the invisible water vapor changes into visible water or ice. In the atmosphere the surplus takes on the form of clouds, fog, rain, snow, hail, dew, or frost, depending upon the conditions under which condensation takes place.

Clouds consist of fine droplets of water or ice crystals. The droplets tend to fall to earth but are often kept floating by upward or transverse air currents. When these droplets grow in size, rain may result.

The amount of rainfall is measured in inches or millimeters. The rain water may be caught in any open, vertical-walled vessel, and its depth measured directly. The standard rain gauge, however, is a cylinder which drains through a funnel into a lower-placed cylinder with a cross-section area one tenth as large as the upper one. Thus, the lower cylinder registers one inch for each one tenth of an inch of rainfall. In this manner it is possible to obtain readings which are more accurate than the direct readings taken in the larger open vessel. Precipitation is best represented on maps by means of lines of equal precipitation, called *isohyets*.

The cooling of the air, necessary to cause condensation of water vapor, may be produced in three ways: (1) adiabatic cooling, that is, cooling by expansion as the moist air rises or is forced to rise; (2) mixing of warm and cold air masses; and (3) cooling by contact with cold surfaces. Of these three, adiabatic cooling is responsible for most of the precipitation of the world. It may be brought about by: (1) convectional currents which may give rise to *convectional rain;* (2) winds ascending mountain slopes and thus producing *orographic rain;* (3) cold air masses wedging underneath masses of moist, warm air and forcing them upward, or warm, moist air being forced to override masses of cooler, heavier air, in either case producing *cyclonic rain.* The heavy rains characteristic of the equatorial belt and the summer thunderstorm showers of the middle latitudes are usually of the convectional type. Mixing of masses of warm and cold air may give rise to the formation of light clouds, but it usually results in little precipitation. Contact with cold surfaces may cause condensation, as dew, frost, or fog, but rarely produces rain.

WORLD DISTRIBUTION OF PRECIPITATION. The type and amount of rainfall are closely related to the pressure and wind belts of the world, as well as to their migrations in the course of a year (Figs. 59 and 60).

The total amount of precipitation during the year is, on the average, greatest in the area between the two tropics. The Equatorial Low-Pressure Belt has the heaviest rainfall, the convectional type prevailing. As this belt moves northward and southward with the sun, convectional rainfall is brought to the adjacent belts, where trade winds prevail during the low-sun season (Fig. 59).

In the subtropical high-pressure areas, air is predominantly in a downward movement. Thus it is warmed, rather than cooled, and relative humidity is low. Considerable land areas in the subtropics, and adjacent portions of the ocean, have little precipitation. In Africa the Sahara region and the neighboring part of the Atlantic Ocean as far as 30° to 35° west longitude have very low rainfall. A similar zone of scant precipitation reaches from Sonora and Baja California in Mexico and southwestern Arizona and southern California in the United States to about 125° west longitude over the Pacific (Fig. 60).

In the trade-wind belts, also, precipitation tends to be low, as long as the trade winds are strong and steady. The comparatively warm air has a low relative humidity, which may become lower yet as the air moves equatorward. However, the absolute humidity of these air masses is not necessarily low. Thus when these winds encounter high land masses, considerable orographic rain may result, as along the east coast of Brazil, on the mountainous islands of the Caribbean area, and along the east coast of Madagascar (Fig. 59).

In the belts of the prevailing westerlies precipitation is largely of the cyclonic type.

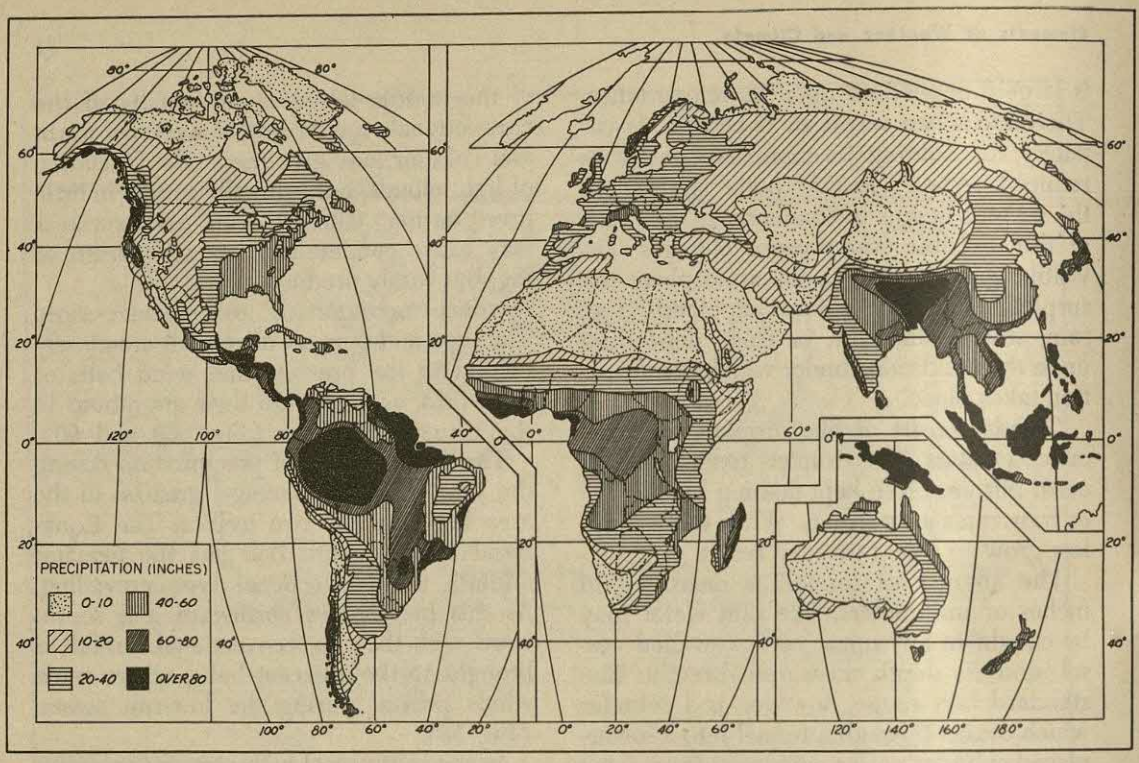


Fig. 60. Distribution of average annual precipitation over the land areas.

It tends to be greatest along the western, windward margins of the continents. Where the mountain ranges rise immediately from these west coasts, as in British Columbia and western United States, orographic precipitation on the exposed slopes is heavy, whereas the eastern slopes are comparatively dry. This contrast is especially marked in the winter season when the eastward-moving air masses are rapidly cooled as they pass over the cold mountain slopes. Where there are no high bordering ranges, as in Western Europe, the moisture is carried farther inland, and precipitation is not as heavy near the coast. In the belts of the prevailing westerlies even the east coasts are fairly well watered, because of the moist air carried inland from the oceans by east and southeast winds which accompany the passage of the cyclonic storms so characteristic of these wind belts.

PRECIPITATION AS A CLIMATIC ELEMENT. From a climatological point of view, the average annual amount of precipitation and the seasonal distribution are most important. Also important are variability of precipitation, intensity of rainfall, and presence or absence of snow.

The annual amount of precipitation is usually stated in inches or millimeters and is popularly referred to as low, moderate, or heavy. In actual practice we think of rainfall in the middle latitudes as being low when it is less than 20 inches per year. From 20 to 40 inches is moderate, and above 40 inches is heavy. However, these figures do not hold true in areas farther poleward or equatorward. In the former, low temperatures prevail, reducing evaporation. Thus, a small amount of precipitation may still be sufficient to cause relatively humid conditions. On the other hand, in tropical regions, with higher temperatures throughout the year, rainfall of less than 40 inches may signify subhumid conditions, with many drought-resisting plants in evidence.

In many regions the seasonal distribution of precipitation is fully as important from climatological and economic points of view as is the total annual amount. For example, the agricultural system of Mediterranean lands is based partly on crops that mature

early, before the onset of the dry summer weather. Early ripening varieties of winter wheat are typical throughout much of the Mediterranean area. Corn, however, which requires considerable summer rainfall, is not an important crop. In the southern Sudan of western Africa, an area of comparatively high rainfall, great seasonal contrasts in the aspects of the landscape and in agricultural activities result from the fact that most of the rainfall occurs during certain months, the remainder of the year being dry, with almost cloudless skies and a searing sun.

Seasonal distribution of precipitation is usually stated with reference to the summer and winter half-year, although sometimes it is necessary to refer to each of the four seasons, or even to specific months.

Variability of rainfall is another important factor. In many areas the amount of rainfall may be twice as great one year as another. This is true in some parts of the tropics, where in one year the rainfall may be as high as 140 inches, and the following year may drop to 70 or 80 inches. On a percentage basis, however, variability is greater in many of the arid and semiarid areas of the world. Even the humid eastern United States is subject nearly every summer to damaging dry spells of unpredictable time of occurrence and duration. Great variability, especially in regions of light rainfall, gives rise to difficult problems of agricultural adjustment.

The intensity of rainfall often determines its usefulness. For example, gentle rains soak into the ground and thus are much more effective in promoting plant growth than are torrential rains. The latter not only give rise to a lower percentage of soak-in, but also cause heavy run-off and resultant soil wash. A smaller amount of rain falling gently is, therefore, more efficient in furthering agricultural activity than is a larger rainfall of torrential type.

Rainfall is one of the most significant elements of climate. Water is the great solvent by means of which plant and animal foods can be converted into tissues and active energy. Thus, where rainfall is scanty, the possibilities for all sorts of organic life are less than where rainfall is abundant. Vast areas of the land surface have little capacity for production because of insufficient rainfall. In these desert or semidesert regions, vegetation is scattered and is specialized to conserve every drop of water. Leaves are small, often wanting, in which case the stems perform the function of the leaves. Cacti and thorny bushes are characteristic examples of arid land vegetation. Crop production may be impossible without irrigation. Over large areas agriculture must be chiefly of the herdsman type. Fixed habitations are not possible in a pastoral economy; in order to live, animals and men must be able to move swiftly from place to place. It is the land of the fleet and the wary, the gazelle and the nomad. If fleetness is lacking, defense must be relied upon, and horny plates and poison fangs come into play. The horned toad and the Gila monster are forms of successful adaptation to the land of little water.

Abundant rainfall coupled with high temperatures is conducive to heavy vegetation. Parts of the Congo basin of Africa and the upper Amazon Valley of Brazil are drenched with rain and covered with dense forest. In both areas, however, vegetation is so luxuriant that it seems to smother both animal and human life. A superabundance of precipitation may be almost as severe a handicap as too little rainfall.

Comparison of rainfall and population maps shows that on the whole the extensive dry lands of the world are sparsely peopled, except in cultivated oases such as the Nile Valley; the bulk of the world's population lives where moderate rainfall prevails. Where there is little rain, dearth of foodstuffs is the limiting factor; where rains are too abundant, man must fight vegetation and disease (Figs. 10 and 60).

SUMMARY

The climatic factors—temperature, wind, humidity, and precipitation—have various aspects which are of importance to the study and characterization of climate. These aspects differ quantitatively over the world. The numerous possible combinations lead to many differences of great importance to

natural vegetation and animal life, to soils, crops, human activities, and general modes of living.

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6

Climates of the World

classification and distribution

EVERYONE KNOWS that every place in the world has a climate peculiarly its own, different in a few or in many respects from that of other sections. The suburbs are reputed to have a better climate than the city, and an area near the water may have a better climate than the adjacent hills, or vice versa. Southern Florida and southern California are claimed by advertising folders to have perfect climates, while the climate of the Guinea coast and other parts of the "deep tropics" is known, at least from the movies, as being something inimical to the white man.

The general public, however, rarely tries to apply a yardstick to such real and fancied characteristics or differences. Climatology attempts to do so, although students of climate do not entirely agree as to what yardsticks should be used. Some emphasize average values of certain climatic elements, singly or in combination; some emphasize deviations from the averages; others, relative frequencies of specific weather conditions; and still others, prevalence of certain types of air masses.

Climatology, like any other branch of science, measures, describes, classifies, and attempts to explain. All four of these go hand in hand, and cannot be separated. Small local climatic differences, such as those between a floodplain and neighboring uplands, or between the suburbs and the city, are the subject of *microclimatological* study, while differences over larger areas are the subject of *macroclimatology* or climatology "proper," which shall be our concern in this chapter.

CLASSIFICATION OF CLIMATE

Not only may climates be classified on the basis of different sets of criteria, but often classifications are made for different purposes. The criteria used for a classification should be adapted to the purpose one has in mind. For example, one might wish to classify the climates of the world or of a continent from the point of view of aerial navigation. For such a classification the criteria used would necessarily be different from those needed to classify climates ac-

cording to the reactions of the human body to atmospheric conditions. From the economic point of view, the most useful classification is perhaps one that emphasizes relationships between the climatic elements and vegetation, including crops.

If one wishes to extend a classification over the entire world, it is necessary to choose climatic elements for which values are available from many well-distributed meteorological stations. A satisfactory world classification based upon frequency of types of air masses, for example, is not as yet feasible since the data are still too incomplete. Temperature and precipitation data are the most readily available data for most parts of the world and for the longest periods, while quantitative data on wind direction, wind strength, humidity, and evaporation are much more scarce. For this reason the major current climatic classifications depend primarily upon temperature and precipitation data, used singly or in various combinations.

One major factor affecting the growth of natural vegetation and crops is soil moisture. This is usually derived from precipitation, although sometimes it is provided by ground water or by irrigation. Direct data on soil moisture content are still very scarce, and if one wishes to classify climates according to the relationships between the climatic elements and crop growing, it is necessary to resort to precipitation data, modifying the value of the total annual rainfall by taking into account average annual temperatures as well as distribution of the precipitation over the year. Thus, in the middle latitudes, where average annual temperatures are moderate, the average annual precipitation has to drop below about 20 inches before conditions of semiaridity are encountered, whereas in the warm tropics semiaridity may result when rainfall is less than 35 inches. The limit between humid and dry areas should therefore be drawn in such a way as to take these differences into account.

Similarly, it is clear that a rainfall maximum which occurs during the warmest part of the year will be less effective as a creator of soil moisture than will a maximum occurring during the coolest part of the year. Therefore, in a climatic classification of the type being discussed, the time of the year during which the rain falls frequently becomes important. For example, see the statement below on the Mediterranean type of climate.

Although the matter is subject to considerable debate, it appears that on the whole temperature distribution is more basic than is distribution of precipitation. The majority of the plant species in the tropics are different from those in the middle and higher latitudes; a great many of the crops also differ. No such pronounced differences exist between the humid and dry portions of each. Therefore, most climate classifications start from the major thermal belts of the earth.

The major climatic zones. On the basis of general temperature distribution and, in addition, differences in the general circulation, we can recognize the following major climatic zones: the tropics, the two subtropical belts, the two belts of intermediate climates, and the two polar areas—seven major zones in all. (See World Map of Climatic Regions.)

TROPICAL CLIMATES. The tropical climates have no frosts, except in a few high mountain areas; in other words, as far as temperature is concerned, they have a year-round growing season. The average annual temperature is above 77°F. (25°C.) and, except at higher altitudes, the average temperature of all months exceeds 65°F. (18°C.). We should not associate extremely high temperatures with this group of climates because, except in desert areas, the thermometer rarely reaches 100°F. The tropics are characterized by monotonously warm and often humid weather, with comparatively little change from day to night and from month to month. Excessive temperatures, such as those attained in summer on the plains of the interior of the United States, are restricted to the drier portions of the tropics. In the Americas, tropical climates extend from central Mexico and southernmost Florida to a line roughly from São Paulo, Brazil, to the southern tip of Paraguay, and from there to Antofagasta, Chile.

In the Old World the tropical climates extend from about the middle of the Sahara

and Arabian deserts, the lower Ganges Valley of India, the lowlands of Farther India, and the Philippines in the north to southernmost Africa and northern Australia.

SUBTROPICAL CLIMATES. The subtropical climates have short, mild winters and long growing seasons. There is a period of one or two months wherein freezing temperatures may occur, though the average temperature of the coldest month is above 43°F. (6°C.). The summer temperatures may be fully as high as those of the tropical climates, but each year there is a short period of cooler weather wherein growth of plant life is arrested or retarded. The winters, although not severe, are sufficiently cold to break the monotony of year-round warmth and to stimulate human activity, thus making the subtropical climates desirable from the standpoint of comfort as well as productivity. During the winter the subtropical areas are in the belt of the cyclonic storms, while in the summer they are located in the "root" areas of the trade winds. They are located immediately to the north and south of the tropical areas.

INTERMEDIATE CLIMATES. The intermediate climates are those which prevail between the subtropical and the polar, often having both the heat of the one and the cold of the other. The term *temperate,* which originated in Western Europe, has become well established for these climates. However, climates such as are found in the interiors of the United States or Eurasia can hardly be considered temperate, and so it seems desirable to refer to them as *intermediate climates* or *middle latitude climates.*

The intermediate climates are areas of conflict between huge masses of cold air, issuing from the polar regions, and masses of warm air from the subtropical latitudes (so-called polar air and tropical air). They have cold winters and warm to hot summers. They vary from areas where the winters are short to those where they are long and severe. They all, however, have the common characteristic of a season of frost as well as a frost-free season. These are the climates of rapid weather changes, caused by cyclonic storms. In many areas with intermediate climate the annual range of temperature is quite considerable, and, especially during early spring and late fall, there may be quick and great daily temperature changes. The most extensive areas of intermediate climates are found in the Northern Hemisphere. In North America, the southern border of the intermediate climates lies in California and from there runs approximately in the neighborhood of the United States-Mexican border to San Antonio, and from there approximately to Montgomery, Alabama, and Charleston, South Carolina. The northern border lies in northern Canada.

In Eurasia the intermediate climates reach as far south as northern Spain and Italy, the Balkans, Iran, and northern China, and as far north as the rim of the Polar Sea. (See World Map of Climatic Regions.)

In the Southern Hemisphere, southern Chile and southern Argentina have intermediate climates, as have Tasmania and New Zealand.

POLAR CLIMATES. The polar climates are characteristic of the high latitudes. They have long, severe cold seasons and short summer periods of mild, rather than warm, weather. Freezing temperatures may occur in all months, and the average temperature of the warmest month of the year is below 50°F. (10°C.). They have no true forests, the poleward limits of tree growth being accepted as marking the approximate limits of the intermediate climates. The milder phases of the polar climates are found in the tundra regions of northern Eurasia and North America, whereas the icecaps of Greenland and Antarctica represent the most severe phases. The polar climates are unfavorable to human life; only along their milder margins can man live, and even there the struggle is disheartening.

Effects of large water and land masses. As has been stated earlier, land and water heat unequally. Air masses formed over or moving over large water areas or uniform land areas gradually take on, at least in their lower levels, some of the characteristics of the surfaces over which they move. Maritime air masses, originating over the oceans, generally contain considerable moisture and are relatively cool in summer and relatively mild in winter. Continental air masses usu-

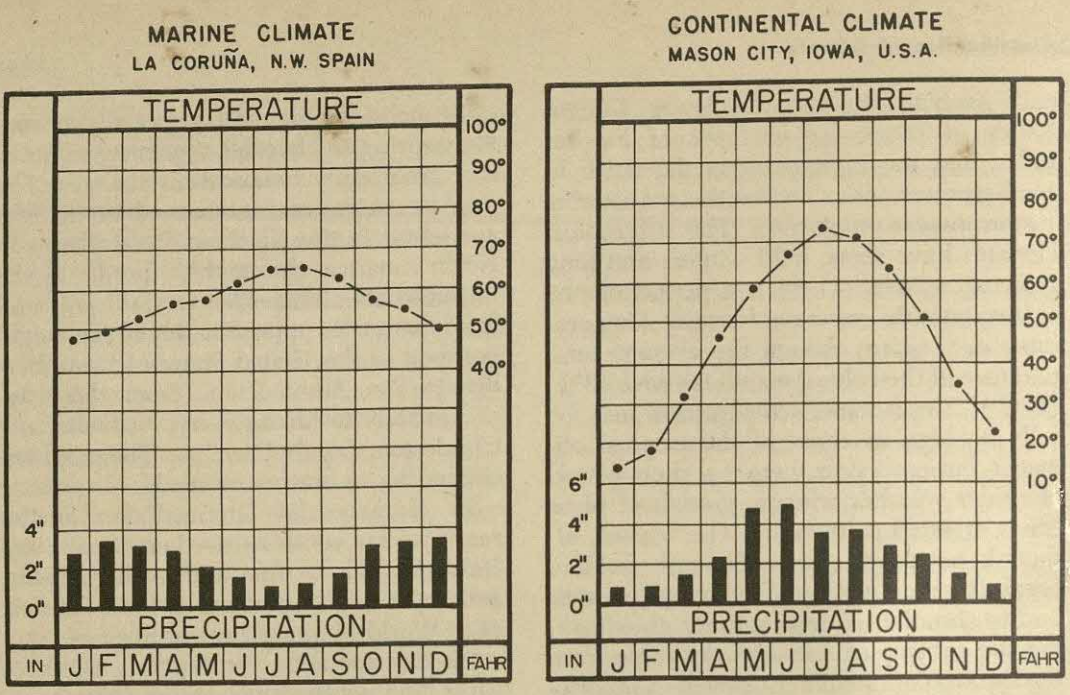


Fig. 61. Comparison of marine and continental climate.

ally contain less moisture and are relatively warm in summer and cold in winter. These effects are felt in the tropics and subtropics, as well as in the middle latitudes, but are most pronounced in the latter.

MARINE CLIMATES. In the middle latitudes, marine climates, characterized by small seasonal and daily temperature ranges, are found on west coasts, where maritime air masses predominate over continental air masses. Summers are cool, and winters are mild. Both the winter minimum and the summer maximum temperatures are usually delayed, February being the coldest month of the year and August the warmest. High humidity and prevailing cloudiness are two of the most typical characteristics of marine climates. Rainfall is ample and well distributed throughout the year, but with a distinct maximum in the late fall (Fig. 61). The marine type of climate is, of course, best developed on islands and on exposed portions of coasts, especially on the west coasts of continents in the middle latitudes, for example, on the Hebrides off the coast of Scotland or on the peninsula of Cornwall, England. Such extreme marine climates may be called *oceanic*.

CONTINENTAL CLIMATES. The continental climates of the middle latitudes have great extremes of temperature, high temperatures being common during the summer and the daytime, and low temperatures in winter and at night. The temperature range generally increases, but precipitation decreases with the distance from the ocean. There is much less cloudiness in the continental climates than in those of the marine type, and the prevailing humidity is lower. The interiors of North America and Asia offer the best examples of well-developed continental climates (Fig. 61).

Effects of altitude. High altitude imparts a certain similarity to climates of widely separated regions. *Mountain* climates are characterized by low air pressures and low temperatures. At high altitudes insolation is intense, since the sun's rays have lost but little energy in their course through the thin and dry upper air. Nevertheless, the air in the mountains remains cool because it is thin, clear, and dry, and it thus has little absorptive power. The light of the sun contains more ultraviolet rays than it does at sea level; this, combined with the low barometric pressure and cleanliness of the air, is responsible for the establishment of sanatoria in many high mountain regions.

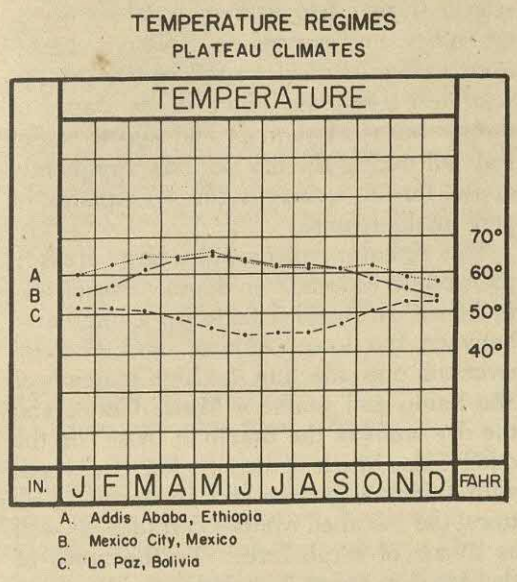


Figure 62.

Mountain climates have a typical zonal arrangement of subclimates. As one ascends, winters become longer and colder, and the climate begins to resemble in many respects that of the polar regions.

Plateaus of considerable altitude and extent generally have fairly uniform climates, in contrast with high mountain regions and their many climatic belts. The climate is cooler than that of adjacent lowland areas, and the annual temperature range is smaller, especially in the subtropics and middle latitudes. In the tropics, the plateau regions, because of their more moderate temperatures, frequently are more favorable for settlement and economic use than are the lowland areas (Fig. 62).

CLIMATIC TYPES

The climates of the world may thus be classified into broad groups on the basis of temperature, and may be further subdivided into *climatic types* on the basis of whether they are dry or humid, whether they have year-round or seasonal rainfall, whether they are continental or marine, or whether they have highland (plateau) or mountain characteristics.

Each climatic type has definite climatic characteristics, typical natural vegetation and native animal life, and, in many cases, typical crops. Different parts of the world with similar climates often show remarkable similarities in their products and productive capacities.

A scheme of subdivision into types, as used on the map of climates of the world at the end of this book, is discussed in the following paragraphs. The exact criteria used in delimiting the various climates and climatic types on the map are stated, and for each type a summary is given of its chief characteristics. This is followed by brief descriptions of the areas where the different types occur.

It must be kept in mind, of course, that the lines that separate the various types do not denote sharp boundaries. In actuality adjacent types usually merge gradually. Only when crossing mountain ranges do we sometimes find sharp changes in climate. Classical examples of such abrupt changes are those encountered when crossing the Cévennes in southern France from northwest to southeast or the Tsinling Mountains of central China from north to south.

The résumé given below should be studied with the aid of a good atlas and should be referred to frequently in connection with the more detailed discussions contained in subsequent chapters. For a discussion of the vegetation formations to which reference is made in the résumé, see the following chapter.

THE MAJOR CLIMATES OF THE WORLD

The tropical climates. The year-round warm climates. All months are frost-free except in high mountains. Average temperature of coolest month is above 65°F. (18°C.), with a few exceptions.

Humid tropical climates

1. *Tropical rainy type.* No prolonged and pronounced dry season. Native vegeta-

tion is characterized by rain forest and jungle which have no seasonal leaf fall. In a few cases a pronounced dry season exists, but precipitation is so high that rain-forest vegetation is possible, for example, along the west coast of India. Temperatures are relatively monotonous, and humidity is high.

This type of climate attains its largest extent in three equatorial areas: northern South America, central Africa, and the Australasian archipelago. In the first area it embraces a large part of the Amazon basin north of the lower Amazon river and west of the Madeira river, one of the major southern tributaries. Much of the area lies politically in Brazil, but it also includes eastern Peru, the "montaña"; eastern Ecuador, the "Oriente"; and southern Colombia. To the north, the three Guianas have the same type of climate. In Africa the tropical rainy climate is found along the Guinea coast from Guinea, through Sierra Leone, Liberia, and the Ivory Coast, to Ghana. After a brief interruption between Akkra, Ghana, and Lagos, Nigeria, the tropical rainy climate resumes its sway. From the delta of the Niger river to the mouth of the Congo river it extends eastward in a broad belt as far as the mountains, high plateaus, and lakes of central Africa. Thus it occupies southernmost Nigeria, the southern part of the Cameroon region, Gabon, and the northern half of the Congo region. In southeastern Asia this type of climate occurs over much of Indonesia, except for the southeastern islands, in most of New Guinea, in Malaya, and the southern and eastern portions of the Philippines. Extensions of the tropical rainy climate are found along the west coast of Colombia, in Panama, and in the eastern and northern parts of the other Middle American countries, including portions of Costa Rica, Nicaragua, Honduras, Guatemala, British Honduras, and even part of easternmost Mexico as far as the Isthmus of Tehuantepec. The coast of Brazil from north of Baía to Rio de Janeiro, the east coast of Madagascar, the west coast of southern India, and the west coast of Burma have the same type of climate.

2. *Tropical savanna type.* Rainfall plentiful part of the year, but pronounced dry season during two to five months (winter or, rather, low-sun season). Native vegetation is characterized by tall coarse grasses, scattered trees, and often, dense stands of thorny bush. Most trees and shrubs suffer leaf fall during the dry periods. Frequently dense forest occurs in the floodplains of perennial streams.

This climatic type occupies large areas in the tropics, especially in South America and in Africa. In Brazil it takes up a huge area between the lower Amazon and Madeira rivers on one side, and the high plateaus of São Paulo and southern Minas Gerais and the dry lands of the Brazilian "nose" on the other side. Much of this region is covered with savanna grasses and scattered scrub trees, the so-called *campos cerrados,* as well as stands of scrub forest. To the north of the Amazon forest it includes the llanos of eastern Venezuela and Colombia and a region of dry-deciduous forests east of the Orinoco river. In Africa the savanna climate extends in a belt almost 400 miles wide from the west coast near Dakar to southern Sudan and Uganda, where it abuts against the highlands of Ethiopia and Kenya. South of the Congo rain forest it embraces another extensive area that reaches to slightly beyond the 10th parallel south, and which is located mainly in the Congo region and northern Angola. The same climatic type is encountered in eastern Africa, extending from southern Kenya, through eastern Tanganyika, to Mozambique, and in part of Madagascar. Most of peninsular India south of the Ganges Valley has a savanna climate. Other areas, of smaller extent, are found in interior Burma, Thailand, Vietnam, the Philippines, southeastern Indonesia, northern Australia, southern Mexico and Middle America, the Yucatan Peninsula, northern Colombia, and in parts of the Caribbean islands.

3. *Tropical highland type.* Rainfall similar in amount and seasonal distribution to that of the tropical savanna. This type prevails at altitudes of about 2,500 to 6,000 feet. Temperatures are lower, owing to altitude. Generally from one to six months with average temperatures below 65°F. (18°C.). There is a small seasonal range of

temperature, but a relatively large daily range.

The tropical highland type is best developed in the highlands, basins, and plateaus of central Mexico; on the plateaus of São Paulo and southern Minas Gerais; in the Ethiopian highlands; and on the plateaus of eastern Africa that stretch from southern Kenya through Tanganyika into Rhodesia and Nyasaland, with a westward extension into central Angola. Central Madagascar also has a highland climate.

DRY TROPICAL CLIMATES

4. *Tropical steppe type.* Rainfall scant; long dry season and short rainy period yearly. There is a greater diurnal range than annual range of temperature. Vegetation is generally of the xerophytic bush type, frequently very thorny; acacias are common, and there is short grass in some areas. Located poleward of the tropical savanna regions. The more humid aspects of this climatic type have a vegetation which constitutes a transition between savanna and true bush steppe.

5. *Warm desert type.* Average annual rainfall less than 10 inches and of irregular occurrence. There is a large diurnal range of temperature. Vegetation is scant and entirely absent in places.

The warm deserts reach their greatest extent in the African Sahara, in Arabia, and in Australia. Parts of these deserts have a climate with subtropical affinities, and during the low-sun season the nights can be distinctly cold. However, aridity and scantiness of vegetation are so much the dominant characteristics of these regions that no practical purpose would be served by an attempt, on the basis of only a few reliable series of temperature observations, to separate the parts that might be termed subtropical. Minor desert areas of this type are located in southwesternmost United States; adjacent Mexico; along the coast of South America from Ecuador to central Chile; in a narrow strip along the southwest coast of Africa between Mossâmedes, Angola and a point north of Cape Town, the so-called Namib; and along the coasts of the African "Horn," which includes parts of Somalia, French Somaliland, and of the Eritrea section of Ethiopia. The Thar Desert of Pakistan is located near the lower Indus river, and, under another name, continues westward along the coast into Iran.

The tropical steppe is found mostly as a transition zone adjacent to the warm deserts. The climate of some of these areas has definite subtropical characteristics, but, again, it would be of little practical importance to set these areas out separately. Contrary to common belief, the Kalahari of southern Africa is an area of tropical to subtropical steppe climate, and not a true desert. Somewhat isolated occurrences of the tropical steppe climate are found in northeastern Brazil (a problem area because of recurring severe droughts), around the Gulf of Venezuela, and in the Argentinian and Paraguayan Chaco.

The subtropical climates. Average temperature of the coldest month is above 43°F. (6°C.), but below 65°F. (18°C.). During the cool season, which lasts one to four months, temperatures may occasionally drop below freezing point, 32°F. (0°C.).

DRY SUBTROPICAL CLIMATES

6. *Dry subtropical type (Mediterranean).* Average annual rainfall generally below 30 inches, in some places below 20 inches. Rainfall occurs mostly during the cool season. In some regions there is a moderate amount of summer rainfall, while others may be nearly rainless during this period. There are about six to eight months with average temperatures below 65°F. Frosts may occur during the coldest period, but there is little interruption of growth owing to low temperatures. This is the prevalent climatic type along west margins of continents in lower middle latitudes, but it is generally restricted to low altitudes.

As the name implies, the Mediterranean climate is best developed along the shores of the Mediterranean Sea, reaching even to the Atlantic coast in Morocco and Portugal. The interiors, and some of the mountain ranges of the countries around the Mediterranean, such as the Spanish plateau, the Apennines, or the Dinaric Alps, have different climates. Elsewhere in the Old World

the Mediterranean type of climate occupies smaller areas: the Perth region of western Australia and western Victoria, and the Cape Town region of the Republic of South Africa. In North America it is found in parts of California, and in Latin America in central Chile.

HUMID SUBTROPICAL CLIMATES

7. *Humid subtropical type.* Rainfall averages above 30 inches per year in most regions; no pronounced dry season. Generally there are four to six months with average temperatures below 65°F. Frost may occur during the coldest period, also some snow. In general, there is slight interruption of growth due to low temperatures. It is the prevalent climatic type along east margins of continents in lower middle latitudes.

The humid subtropical type of climate is not as distinct as the Mediterranean type. This climate attains considerable extent in southern United States; southern China; and in an area that embraces the southern states of Brazil–Paraná, Santa Catarina, Rio Grande do Sul–Uruguay, the lands between the Uruguay and Paraná rivers in Argentina and southern Paraguay, and part of the province of Buenos Aires. In the United States this climatic type merges almost imperceptibly with the intermediate climates to the north, and it is rather difficult to draw a satisfactory line. In Argentina the southern part of the area shows many characteristics of the intermediate climates. Only in China is the separation from the intermediate climates somewhat more distinct, largely as a result of the existence of a west-east mountain range, the Tsinling Mountains, and the Hwai Hills, which continue the range southeastward toward the lower Yangtze river in the neighborhood of Nanking. Southern Japan, although located farther north, has a humid subtropical climate due to the moderating influence of the Pacific and some shelter from the cold blasts that come out of northeastern Asia in winter. Smaller areas of this type of climate are found as rather narrow coastal strips in the Republic of South Africa and in the Australian states of Queensland, New South Wales, and Victoria.

The intermediate climates. Have both frost-free and frost-certain periods each year. Hot summers and cold winters are characteristic. Continental phases with pronounced seasonal extremes occur in the interiors of North America and Eurasia; marine phases predominate near the west coasts of these continents. Along certain east coasts ocean-modified variants from true continental conditions occur.

HUMID INTERMEDIATE CLIMATES

8. *Humid continental type.* Average temperature of coldest month below 42°F. (6°C.), but not more than four months with average below freezing point (32°F.). There are more than three months with average temperatures above 50°F. (10°C.), and the growing season, free of severe frosts, lasts three months and longer. The average annual range is more than 36 Fahrenheit degrees (20 Centigrade degrees). Average annual rainfall is over 20 inches, with heaviest rainfall occurring during the warm season. This climatic type can be divided into two subtypes: (1) nine months or longer with average temperatures above freezing point (32°F.); (2) less than nine months with averages above freezing.

This climatic type is not found in the Southern Hemisphere because of a lack of land masses of sufficient extent. In North America it occupies a large area east of approximately the 100th meridian, north of the region of humid subtropical climate, and west of a comparatively narrow coastal area. It includes a bit of Quebec, southern Ontario, and reaches northwestward into the Canadian Prairie Provinces. In Europe this climate is found east of a line approximately from Gdynia, Poland, to the upper Danube river, and it stretches from there eastward into Eurasia, including much of central and southeastern Europe. Beyond the Ural Mountains, marked on the map by the sharp indentation in the line between this climate and the subpolar type, it becomes a rather narrow belt, about where the Trans-Siberian railroad is located. In eastern Asia it occupies much of northern China proper and Manchuria.

9. *East coast continental type.* Occurs

along the east coasts of North America and Asia between latitudes 35° and 50°N. Average annual temperatures are not greatly different from those of the same latitudes in the continental interiors, but seasonal extremes are not so pronounced. The influence of the ocean, carried over the land by cyclonic storms, results in a retarded advent of seasons, smaller range of seasonal temperatures, and a relatively uniform distribution of precipitation in all months of the year. There are heavy winter snows, in contrast with the light snowfall of continental interiors.

This climatic type is rather limited in extent. In North America it forms a rather narrow coastal belt from New Brunswick to Cape Hatteras, the western limit of which is somewhat difficult to define with accuracy. In eastern Asia it is limited to the northern half of the main Japanese island, Honshu, and the island of Hokkaido to the north.

10. *West coast marine type.* Average annual range of temperature less than 36 Fahrenheit degrees (20 Centigrade degrees). Rainfall is abundant and fairly well distributed throughout the year, with a tendency toward an autumn maximum. Native vegetation varies from mixed hardwoods to solid stands of conifers.

The west coast marine climate is very important in western Europe, where it reaches from the northwestern corner of the Iberian Peninsula to beyond Trondheim in Norway. This climate, beneficial to agriculture, embraces all of the British Isles, most of France, all of Belgium and the Netherlands, West Germany, East Germany, the coastal area of Poland, Denmark, and sections of Norway and southern Sweden. Elsewhere it occurs only in comparatively narrow belts, as along the North American coast from northwestern California, through Oregon, Washington, and British Columbia to Alaska, and as a similar narrow belt in southern Chile. New Zealand and Tasmania belong to the same climatic type.

11. *Subpolar type.* More than four months with average temperature below freezing point, and at most three months with average temperatures above 50°F. Rainfall is lower than in other humid temperate climates, but it is efficient because of the low rate of evaporation. This climate type includes much of the temperate coniferous forest belt.

The subpolar climate is absent in the Southern Hemisphere. In North America it forms an unbroken belt from western Alaska to southern Labrador and Newfoundland. In Alaska it is about 250 miles wide, but in Canada it attains a width of about 600 miles. A similar belt stretches from west to east across Eurasia, beginning in Sweden and continuing throughout the entire width of the Soviet Union to the shores of the Sea of Okhotsk. In eastern Siberia this belt attains a width of 20 latitude degrees, or approximately 1,375 miles.

Dry intermediate climates

12. *Middle latitude steppe type.* Low annual rainfall (6 to 20 inches) with summer maximum is the chief characteristic. There is a wide temperature variation. The humidity is low in warmer areas. Natural vegetation in the cool and more humid areas varies from short grass cover to sage brush and scattered bunch grass; in warmer and less humid areas thorny bush and mesquite are dominant over the grasses.

13. *Middle latitude desert type.* Similar to the steppe type, except that rainfall averages less than six inches per year and vegetation is scantier, varying from scattered thorny bush to complete bareness.

The largest areas of middle latitude desert are located in interior Asia: the Kara Kum, Kyzyl Kum, and some smaller deserts of Russian Turkestan; the Takla Makan of Sinkiang, China, the Gobi of Mongolia, and the Dasht-i-Kavir and Dasht-i-Lut of Iran. In North America a comparatively small middle latitude desert area is found in part of Nevada and adjacent California, and in South America a similar desert region lies in southwestern Argentina.

Associated with the deserts of interior Asia there is a great belt of middle latitude steppe climate that reaches from the mouth of the Danube river in Romania across the Soviet Union to Manchuria. Other such areas are found in Turkey, Iran, and along

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the foot of the mountains of central Asia. In North America a broad zone of the same type of climate lies to the west of the 100th meridian, embracing much of western United States, and extending northward into Canada and southward into Mexico. Smaller areas of middle latitude steppe climate are found in Argentina, the Republic of South Africa, and Australia.

The polar climates. Average temperature of the warmest month is below 50°F., and freezing temperatures may occur in all months of the year. Low temperatures prevent growth of trees. Rainfall is largely in the form of snow, but, measured in inches of water, it is not heavy.

14. *Tundra type.* Average temperature of the warmest month is above freezing but does not exceed 50°F. There is vegetation of mosses, annuals, grasses, sedges, and low, often nearly flat-lying bushes.

15. *Icecap type.* Average temperature of the warmest month is below 32°F. There is no vegetation.

The tundra type climate occupies the northern rim of the Northern American and Eurasian continents. The icecap climates are limited to Antarctica and the interior of Greenland.

The mountain or high altitude climates. Mountain climates are characterized by such a variety of differences, owing to local conditions, that definite criteria cannot be established, nor can any specific general characteristics be described. In temperature they range from tropical to polar, and in vegetation from rain forest to desert.

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7

Climate, Soils, and Agriculture

In some regions of the world the farmer may grow wheat as a subsistence food or cash crop; in others he grows rye and in still others, millet, rice, bananas, or manioc. In certain sections he may specialize in the production of cranberries, in others in that of cacao, rubber, or tobacco. In parts of the world he may keep few or no domestic animals; elsewhere he may raise many hogs or concentrate upon keeping cows for milk, butter, and cheese. None of this is accidental; the type of crop produced or the type of animal raised rarely depend upon the whim of the individual farmer.

FACTORS THAT INFLUENCE AGRICULTURAL PRODUCTION

The nature of agricultural production in any part of the world is the result of the interplay of a large number of factors, many of which may be of a geographic or economic nature, whereas others may be psychological or sociological.

Psychological and sociological factors. Food prejudices, which probably are essentially psychological in nature, play a role, pro or con. For a long time, for example, production of beet sugar was hampered by the idea that sugar from beets was different from, and inferior to, sugar from cane. Rice is a grain of warm regions. Nevertheless, if one looks at a map of rice production in China, it will be seen that some of the rice is produced far north in Manchuria, where climatic conditions are rather unfavorable for this crop. The Chinese who settled in this area brought with them the taste for rice, and wherever it is possible they try to grow at least a little of it. Socio-religious factors may be very important. On a world map showing geographic distribution of swine, the almost complete absence of this animal in the Near East and northern Africa is very striking. In similar conditions and latitudes elsewhere hogs are numerous. The Near East and northern Africa are regions where the Islamic religion is predominant, and according to its precepts pork must not be eaten.

Economic factors. More important than psychological and sociological factors are

economic factors, particularly in areas where man carries on commercial agriculture, and where a monetary profit is the principal aim of his activities. Access to market, cost of transportation to market, and the question as to whether a crop can be sold at a profitable price in such market become factors which exert a profound influence upon the type of agriculture that is carried on. Also, the fact that one crop which can be grown in an area will yield considerably larger profits than five or six others that can be grown equally well, often largely determines the aspect of agricultural production in the area concerned. As it is frequently expressed, one crop can out-compete the others for the land. In this way corn in much of Iowa can out-compete wheat for the land, so that in that state the corn acreage is large and the wheat acreage insignificant.

Physical geographic factors. More basic than all of these considerations, however, are the questions of whether physical conditions make it possible to produce a certain crop, and whether these conditions are sufficiently favorable to lead to reliable and profitable yields. Agricultural production, more than almost any other form of production, depends to an important degree upon the factors of the physical environment. In the case of crops, the major part of the production process—that is the vegetative growth, the blooming, the setting of the seed, and the ripening of the seed—involves various processes of Nature. These processes are slow and generally take their own appointed time. While man can speed up machines, often at will, there is comparatively little he can do to speed up the basic process of photosynthesis and other natural processes responsible for the growth of crops. Thus, a most fundamental difference between agricultural and manufacturing production is that of *tempo*.

In manufacturing, man can easily regulate quantity and quality of output, but in the case of agricultural production both quantity and quality depend to a considerable extent on the conditions of the physical environment. These may either be general conditions, such as poor soils or good soils, a favorable climate or an unfavorable climate, or they may be conditions during one particular growing season, such as an unexpected period of drought or a season of unusually well-distributed rainfall.

Man can modify the factors of the physical environment but only to a limited extent, and whatever he does requires extra effort or money, which usually takes the form of capital expenses and, in addition, operating expenses. Where drought is perennial or seasonal, man can, of course, irrigate to the extent of the amount of water available (which is always very limited in such areas). Irrigation possibilities are further circumscribed by the fact that the right types of landforms must be available for irrigation. The areas to be irrigated should be quite level and should have a slope in the downstream direction and a slope toward the stream, so that the water can be easily led onto the fields, and the surplus water can be drained off easily. It usually is too costly to artificially terrace areas with an unsuitable, uneven topography. Areas of land with a topography suitable for irrigation are generally rather limited in extent. Besides, irrigation works, such as dams, canals, and ditches, not only cost money for the original construction, but their cost of maintenance is usually quite considerable. Interest on capital plus annual maintenance expenditures force the farmer to grow crops of relatively high value, unless he is subsidized by the taxpayer. Man can even create an entirely artificial environment for crop production, such as he does in hothouses, where almost everything, soil, soil moisture, humidity, temperature, and even light, may be artificial. However, the high expenditures necessary for this mode of production are warranted only for crops of very high value, such as flowers (especially in winter) or large, out-of-season table grapes. The great bulk of the world's agricultural products are grown under natural conditions, with man, at most, making some efforts to improve the soil and keep down competing weeds.

Under such conditions climate and soil become factors of prime importance in agricultural production. In general it may be stated that climate is the principal basic factor that influences the geographic distribution of crops, and even that of livestock. Soil is second in importance, although there are a number of crops whose quality seems to depend more upon certain peculiar characteristics of the soil than upon the climate.

The principles of weather and climate have been studied from a general point of view in preceding chapters. Climatic conditions in various parts of the world are discussed in more detail in connection with each of the major climatic regions and the major crops and agricultural activities in each of these regions. In this chapter we study the nature of soils and some of the principal relationships between climate, soils, and agricultural productivity.

VEGETATION FORMATIONS OF THE WORLD

There is an intimate relationship between climatic conditions and the major aspects of natural vegetation. This relationship is so close that names of *vegetation formations* (major groups of plants that live together in a natural state) are often used for climatic types, such as *savanna* and *steppe* climate. In turn, there is a close relationship between original vegetation and soils. For example, although other factors entered in, the soils that developed under the tall grasses and short grasses of the American prairies are quite different from those that developed under forests in immediately adjacent areas. Soils which have developed in a coniferous forest may be quite different from soils developed in nearby areas of broad-leaved forest. The relationships between climate, natural vegetation, and soils are vastly more complicated than can be discussed within the scope of this book. However, in order to gain an idea of the major relationships concerned and the gross pattern of soil distribution resulting from these relationships, it will be well first to have a look at the principal vegetation formations.

The vegetation formations of the earth can be classified broadly into four major types: (1) forest, (2) savanna, (3) grassland, and (4) shrub. Since the climatic conditions largely responsible for the distribution of these types do not have sharp boundaries, the vegetation formations also are rarely separated by sharp lines. Therefore, it is not possible to define the exact margins of the various types or of their subtypes, but the lines on the vegetation map simply mark the places where one formation ceases to predominate and another becomes dominant (Fig. 63).

In general, forests occur in regions of heavy to moderate rainfall; grasslands and savannas occur where rainfall is moderate to light; and deserts occur where the rainfall is scant. These generalizations are helpful in correlating vegetation with climate in the different parts of the world.

The native vegetation is of importance not only in connection with the nature and distribution of the major soil groups, but also as an indicator of possible agricultural use of the land in areas for which little or no direct information on soils is available. Finally, it is frequently of prime importance as a basic economic resource, providing pasture, timber, firewood, and a host of other products. The major types and their principal subdivisions can be described in rather simple terms. Such descriptions enable us to see more clearly the relationships among the groups and the environments in which they occur.

1. Evergreen tropical rain forest. This type of broad-leaved forest is found in the rainy lowlands of low latitudes, as, for example, in the Congo basin and in the lower Amazon Valley. The trees have no periodic leaf fall, and the forest is ever clothed with verdure. Numerous varieties of trees and mixed stands are the rule. It is predominant in climatic type 1 (see p. 99).

2. Evergreen subtropical forests and bush. In this class belong the stands of evergreen trees and bushes in lands with a Mediterranean climate. These occur where

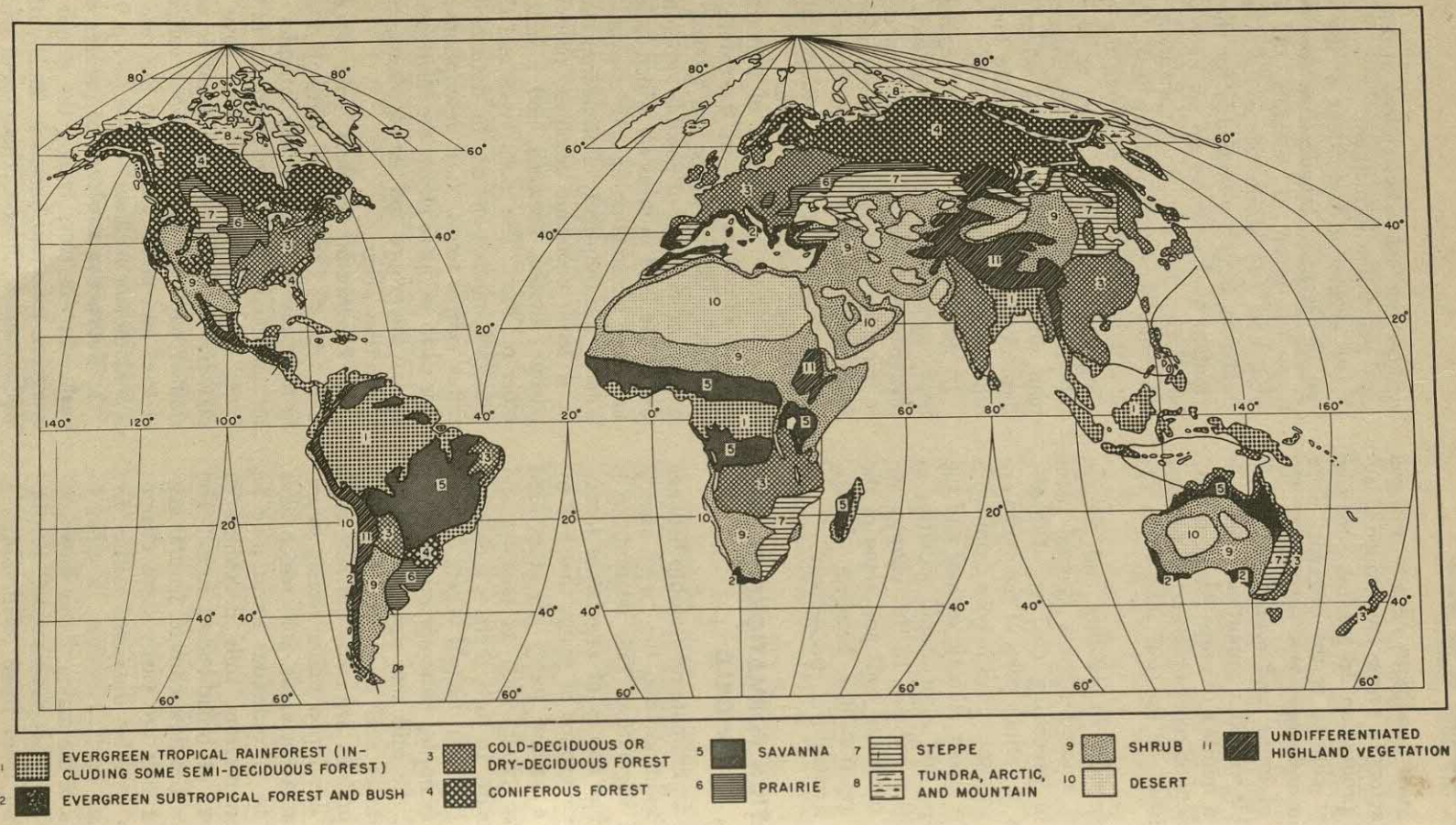


Fig. 63. A generalized map of the major vegetation formations of the world. In many parts of the world these formations have partly or wholly disappeared due to man's activities.

there is summer drought and moderate winter cold, and they consist of species which have developed tolerance of such conditions.

3. Cold deciduous or dry-deciduous forests. This type of broad-leaved forest is characterized by periodic leaf fall induced either by seasonal drought or by seasonal freezing temperatures. Wide distribution is characteristic, notable examples being found on every continent. Among the best known are the mixed hardwood forests of eastern United States, such as the oak-hickory forest or the beech-birch-maple forest. There the leaf fall is induced primarily by the freezing temperatures of approaching winter. Dry-deciduous broad-leaved forests are found, for example, in Africa, parts of Australia, and along the west coast of Central America, where seasonal drought induces leaf fall. The teak forests, for example, of Burma and Thailand, are typical tropical dry-deciduous forests.

4. Coniferous forests. This type of narrow-leaved forest is widely distributed over the continents. It occurs at moderate to high altitudes in the low latitudes, where elevation causes climatic conditions such as are characteristic of middle latitudes. The most extensive areas, however, are in the higher middle latitudes, where vast forests consisting of almost solid stands of pine, spruce, or fir occur. Notable examples of this type are the forests of northwestern United States, those of the Rocky Mountains, the forests of northern Canada, and those of Scandinavia, Finland, and northern USSR. This type of forest is predominant in climatic type 11 (see p. 103). However, it is also extensive on sandy soils of southeastern United States and in southern Brazil.

5. Savannas. This type consists of stands of tall, coarse grasses wherein are found scattered trees or clumps of trees. Savannas may be considered to be transition zones between the forests and the short grass and bush of low latitudes, although the term is also used to include some wet grasslands in the middle latitudes where scattered tree growth occurs. Perhaps the best-known example of an extensive savanna area is the Sudan of Africa, south of the Sahara Desert. It is predominant in large parts of climatic type 2 (see p. 100).

6. Prairies. These areas of tall, but comparatively fine grasses occur in the middle latitudes. Tall grasslands are the response to moderate rainfall, generally above 20 inches per year. In such areas the growth period lasts throughout a fairly long summer and is terminated by the low temperatures which mark the advent of winter. The original prairies of the central Mississippi Valley area, the pampas of Argentina, and of the Black Earth Belt or Chernozem Belt of Russia are the best-known examples. Most of these areas have been turned into agricultural land.

7. Steppes. These short-grass regions of the middle latitudes occur where the annual rainfall ranges from 10 to about 20 inches a year and comes mostly in the spring and early summer. The grass dies down without harvesting, thus furnishing brown pastures throughout much of the season of drought. The best-known examples are the Great Plains east of the Rocky Mountains and the extensive steppes of southern Russia.

8. Tundras. The tundra is not a true grassland, but its resemblance thereto is marked. It is limited to areas wherein cool to cold weather occurs all year and where evaporation is so slow that even moderate rainfall gives rise to relatively humid atmospheric and soil conditions. The vegetation is low and sprawling, mostly grasses, annuals, mosses, and very low shrubs. The tundra areas of northern Siberia are the mostly widely known, but similar conditions prevail over large areas of northern Canada.

9. Shrub. Shrub vegetation occurs generally where poverty of the soil, low rainfall, or strong winds make normal tree growth impossible. The drought-resistant shrub of the Mediterranean region called *maquis,* or *macchia,* is one typical form, as is the *mesquite* of southwestern United States. Other forms are the scrub formations of some of the semiarid tropical regions, such as the northern Sudan and parts of Australia.

10. Desert. Desert vegetation is char-

acterized by scattered, often thorny shrub and widely scattered tufts of grass, which are dried up most of the year and show life only after infrequent showers. It is the poorest of all types of vegetation.

In many parts of the world the natural vegetation has wholly or partly disappeared to make way for man's tilled fields, meadows, or pastures, but the effects of the original vegetation upon the soils can still be seen or inferred, and wherever man abandons the land, natural vegetation tends to take over again. This process of restoration is slow in some areas, particularly in dry regions and in areas where the soil has been badly damaged by misuse, but it is comparatively rapid in warm, humid regions, such as in the rainy tropics. However, the vegetation that springs up naturally on such abandoned lands is frequently different from the original vegetation of the area concerned, and it may take many decades, sometimes even several hundred years, before it has fully reconstituted itself. In some cases it apparently never comes back to what it was before man entered upon the scene.

THE NATURE OF SOILS

The most valuable part of the earth is the surface film of soil, only a few inches to a few feet thick. If this thin veneer should disappear, food plants could not grow, land animals would starve to death, and the few remaining human beings would have to cling to the coasts, competing for the insufficient seafood. There would be no lumber for houses, no wood pulp for newspapers, and no cotton, wool, rayon, or leather for clothing. Yet, in the United States alone, unwise use of the land since the arrival of the white man has ruined enough of this precious veneer to render millions of acres of cropland unfit for cultivation. In large parts of the world no adequate steps have been taken to preserve the topsoil. The first step toward wise policies regarding the use of soil is an understanding of soil itself.

Loose, unconsolidated earth materials are often called soil, although they should be referred to as mantle rock. Only the highly weathered upper layers, which have been influenced by climate, plant growth, and microorganisms, can be termed soil.

Thus, the soil is the upper part of the mantle rock, which, as a result of physical and chemical changes—owing to weathering; the leaching and depositional activities of soil water; the presence of soil bacteria, other organisms, and decaying vegetable and animal matter; and other factors—has developed certain characteristics of its own. This development makes the soil into something quite different physically and chemically from the underlying material from which it was derived. A soil should be looked upon as a living entity because without bacteria and other organisms it ceases to be soil, and becomes fossilized.

Different underlying, or so-called parent, materials may have developed soils which are quite similar. However, one should not go so far as to deny the importance of the nature of the parent material. In the Shenandoah Valley of Virginia, for example, the soils developed upon the limestones differ greatly in agricultural value from those developed on the shales. Similarly, soils developed upon sands can never be the same as those developed upon adjacent clays.

CHARACTERISTICS OF SOILS

Among the qualities of the soil most commonly recognized are texture, structure, thickness, color, and the presence or absence of hard layers, known as *hardpans*, near the surface.

Texture refers to the size of the particles that constitute the soil. If the texture is too coarse (coarse sand), the soil is quite likely to let water pass through too rapidly and thus be droughty. If the texture is too fine (clays), the soil tends to be compact, drains slowly, and is difficult to cultivate. However, through careful and situable means of cultivation such soils can often be made highly productive, such as, for example, the marine clays of the Netherlands. Soils which are of medium texture (loams) tend to absorb and retain moisture, are readily tilled, and are usually favorable for tillage agriculture.

By *structure* we mean the arrangement of the soil particles within the mass. Studies have revealed this as a most important property in accounting for soil differences. It involves factors too complex for detailed treatment here, but in a simple way we may think of soil particles as being arranged in thin layers or plates, rough cubes, small columns, irregular granules, or as having no arrangement at all. A granular arrangement is highly suitable for tillage purposes. The water-holding capacity of the soil, its adaptability to cultivation, and even its productive capacity are, in most cases, directly related to its structure.

The *color* of a soil depends upon its mineral and organic content. In general, brown and reddish soils owe their color to the presence of *iron hydroxides*, of which ordinary iron rust is the most common example. Dark soils, approaching a black color, are usually rich in *carbon*, generally in the form of decayed organic matter. Color in itself is not proof of fertility, but generally people prefer dark-colored soils because organic content is essential to vigorous growth of most plant life.

The *thickness* of soils, i.e., of the living entity referred to above, varies greatly. In very dry regions, the soils usually are thin, but in subhumid regions, such as former prairie regions, soils were quite thick in their original state. Of course, thin soils generally are less promising for agricultural purposes than thick soils.

Soil stratification. In vertical section we usually recognize three more or less distinct layers or strata commonly referred to as the A, B, and C *horizons* (Fig. 64). Near the surface bacterial action on surface and subsurface plant debris contributes humus to the soil. After a period of time the upper layer, through humus accumulation, leaching, and redeposition, may become so changed that it may bear but slight resemblance to the original materials. This highly altered zone is commonly termed the A horizon. It is best developed, as to quality and depth, in the soils of the temperate climatic belts in which the rainfall is moderate.[1]

[1] Rainfall of about 25 to 40 inches.

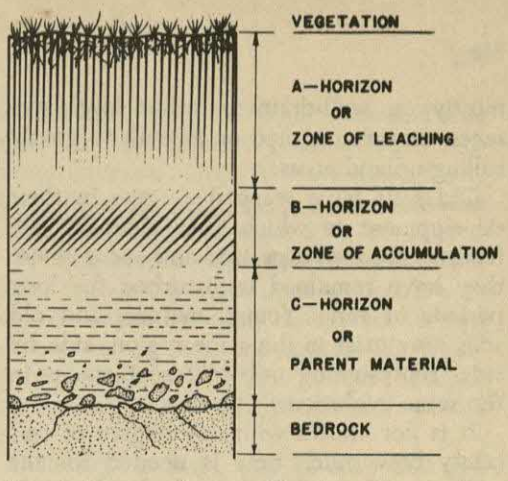


Fig. 64. Diagram showing soil horizons.

Below the A horizon follows usually a layer of varying thickness, termed the B horizon, wherein only partial alteration of parent material has occurred, and in which materials removed from the A horizon may have been redeposited. This horizon has characteristics that make it different from both the overlying and underlying zones. There may be differences in texture, color, compactness, and content. The B horizon is commonly termed the *subsoil.*

Under the B horizon lies the little-altered parent material, termed the C horizon. Where the mantle rock is shallow, there may be not much C horizon, but where it is deep, as, for example, on the extensive alluvial plains or on the loess plains of the Middle West, the C horizon gradually leads into the mantle rock proper.

Soil development. It has been generally recognized that soils pass through cycles of development. On the basis of this observation soils may be referred to as *young, mature,* or *old,* according to the stage of development which they have reached.

Young soils are incompletely developed and often occupy slopes, where constant erosion prevents further development, or floodplain areas, where the cycle of evolution is frequently interrupted by the deposition of new sediments.

Mature soils are those which, undisturbed by erosion or deposition, have acquired characteristics distinctly different from those of the underlying material. Such soils occur

mostly on well-drained, rather level surfaces, on terraces, and on smooth to gently rolling upland areas.

Old soils have reached a stage in their development in which their characteristic features are well expressed and occur where they have remained undisturbed for long periods of time. Young, mature, and old soils may exist in the same region, side by side, representing only different stages in the same evolutionary process.

It is not known with any degree of certainty how much time is needed for the evolution of a soil. Some soils develop very slowly, as attested by the fact that in many parts of the world there are soils which must have developed under climatic and vegetation conditions different from those now in existence. Present climatic conditions have only modified these soils. This is the case, for example, with the "degraded" chernozems of the USSR which were so named by Russian soil scientists in order to distinguish them from the chernozems proper. They developed essentially under a climate somewhat drier than that of the present time, but became leached or degraded when to the north of the present Chernozem Belt the climate became somewhat more moist. Also, it seems that many tropical soils evolve more rapidly than soils in the cooler regions of the world. As to soil quality, it is difficult to make generalizations on the basis of age. A very young soil, as, for example, one that has just started to develop upon a recent volcanic ash deposit, may be too young for optimum vegetation conditions, whereas a young alluvial soil, rejuvenated annually by suitable deposits of silt and other matters as a result of stream overflow, may be just about right. Old soils may be good soils, as, for example, an old chernozem, but in the tropics old soils usually are very poor. The same is true of old, well-developed podzols.

MAJOR SOIL GROUPS

The processes of weathering and the leaching and depositional activities of soil water differ according to climatic conditions. Natural vegetation formations, themselves partly a response to climatic conditions, differ greatly from region to region and contribute varying amounts and kinds of organic matter. Finally, there are many differences in soil texture, owing to differences in parent material and other circumstances. Thus the number of soils which can be recognized in the world is very great.

Various schemes of classification have been suggested, most of them rather complicated, in order to accommodate the many types of soils known to exist. The great "zonal," or major soil groups, first recognized by Russian scientists, have since been studied in other parts of the world. The American system of soil classification is in essence derived from the Russian morphological classification and is based primarily upon visible and physical characteristics of the soils, with secondary attention paid to the chemical characteristics.

The most important soil groups are the following (Fig. 65):

1. Tundra soils (1). These soils have dark brown peaty layers at the surface, over grayish horizons. Often parent material underneath is permanently frozen. They occur in high latitudes, under tundra vegetation.

2. Podzols (2). A thin layer with poorly decayed organic material due to limited bacterial activity lies on top of a badly leached grayish horizon, under which lies a dark brown layer, often quite consolidated as a result of the redeposition of iron hydroxide and aluminum hydroxides. This type of soil occurs in higher latitudes, in regions of cold and moist climate. The natural fertility of these acid soils is low.

3. Gray-brown podzolic soils (7). The arrangement of layers is essentially the same as in the podzols, but the soil is not as acid. The top layer is thicker; contains more humus, which, as a result of bacterial activity, is much better decayed than in the case of the podzols; and is less leached. These soils develop under deciduous and mixed deciduous-coniferous forest, in areas of moist climate with a cool to cold winter. Their fertility is medium.

4. Prairie soils (3). These are deep, very dark brown soils, which get lighter colored at a depth of from three to five feet, where they grade into lighter-colored parent material. They develop under the tall grass prairies of the middle latitudes, where not too humid conditions prevail. These soils are nearly neutral in reaction and of high fertility.

5. Chernozems (4). These soils have a very dark brown, almost black top layer, which is from one to four feet thick and is underlain by a light-colored horizon rich in lime, often with whitish lime streaks. They develop under tall-grass prairie of subhumid regions in the middle latitudes. Their fertility is high, but their productivity is often considerably reduced by insufficient soil moisture.

6. Chestnut and brown soils (5). These are dark brown to brown soils, decreasing in thickness as the color becomes lighter. Under the dark top layer lies a whitish horizon rich in lime. These soils are typical for steppe regions in the middle latitudes. Fertility is high, but productivity is impaired by droughts.

7. Yellow and red humid subtropical soils (12). These soils have a rather thin layer containing organic materials, which rests upon a yellowish-brown leached horizon, which in turn lies on a deep red or yellowish layer. The reddish soils were developed primarily under deciduous forest, and the yellow soils under coniferous forest in areas of moist and warm climate of the lower middle latitudes. Their fertility is from medium to low. Terra-rossa soils are red soils in areas of Mediterranean climate, usually on limestones.

8. Lateritic soils. Due to vigorous bacterial activity, these soils have little organic material in the top layer, and what they have is well decayed. Leaching has affected not only the plant salts and the lime, but also has removed part of the silicates. The upper layers have a low silica content but a high content in aluminum and iron hydroxides. They are soils of humid tropical regions. Their fertility is low. Major subdivisions of these soils are: (11) yellow and red lateritic soils, (13) slightly leached soils under dry-deciduous vegetation, (10) red-brown savanna soils, (15) red-brown lateritic soils on basalts, (16) eroded lateritic soils, and (9) steep-slope soils of tropics.

9. Sierozems and desert soils (16). These soils are grayish in color and low in organic matter. A highly calcareous horizon often lies close under the surface. The fertility of the soils may be from medium to high, but in order to produce, irrigation is necessary.

Soils rich in lime, that is, soils that are lime-accumulating in the upper horizon, are called *pedocals;* soils characterized by a relatively high iron and alumina content which are not lime-accumulating as a result of leaching by soil water are called *pedalfers.* Pedalfers usually tend toward acidity, whereas pedocals give alkaline reactions. In any mature soil the amount of lime is directly related to the moisture conditions under which the soil has been developed. The mature soils in arid and semi-arid areas are generally rich in lime, but in areas of abundant rainfall they are deficient. Since rainy lands are usually covered with forest, whereas subhumid lands are occupied by prairie and steppe vegetation, the pedalfers are known also as *forest soils* and the pedocals as *grassland soils.* But in such a generalization we must recognize, for example, that the prairie soils of the United States, which are grassland soils, are not lime-accumulating, at least not under present climatic conditions.

The presence of lime in the soil is often an indication of fertility. If lime is present in fair quantity, other soluble minerals essential for plant growth—such as phosphates, nitrates, and potash—are usually also available more or less abundantly. Thus not only are the essential mineral constituents present in such form and in such quantities that they can serve as plant foods, but the presence of such minerals is conducive to a stable soil structure, favorable for both tillage and plant growth. Very acid soils, on the other hand, are weak in the essential plant foods named above, and usually their physical structure is less favor-

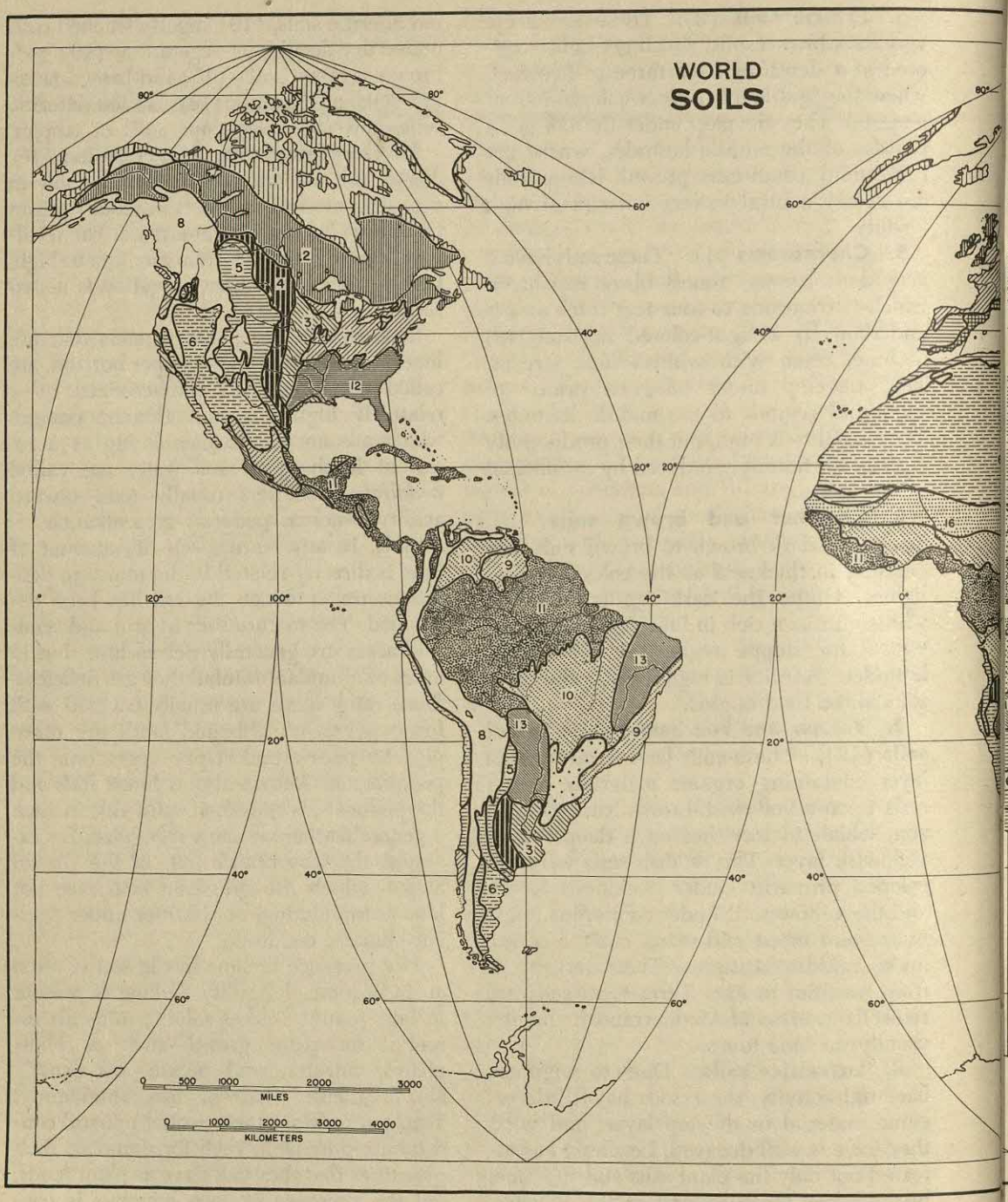
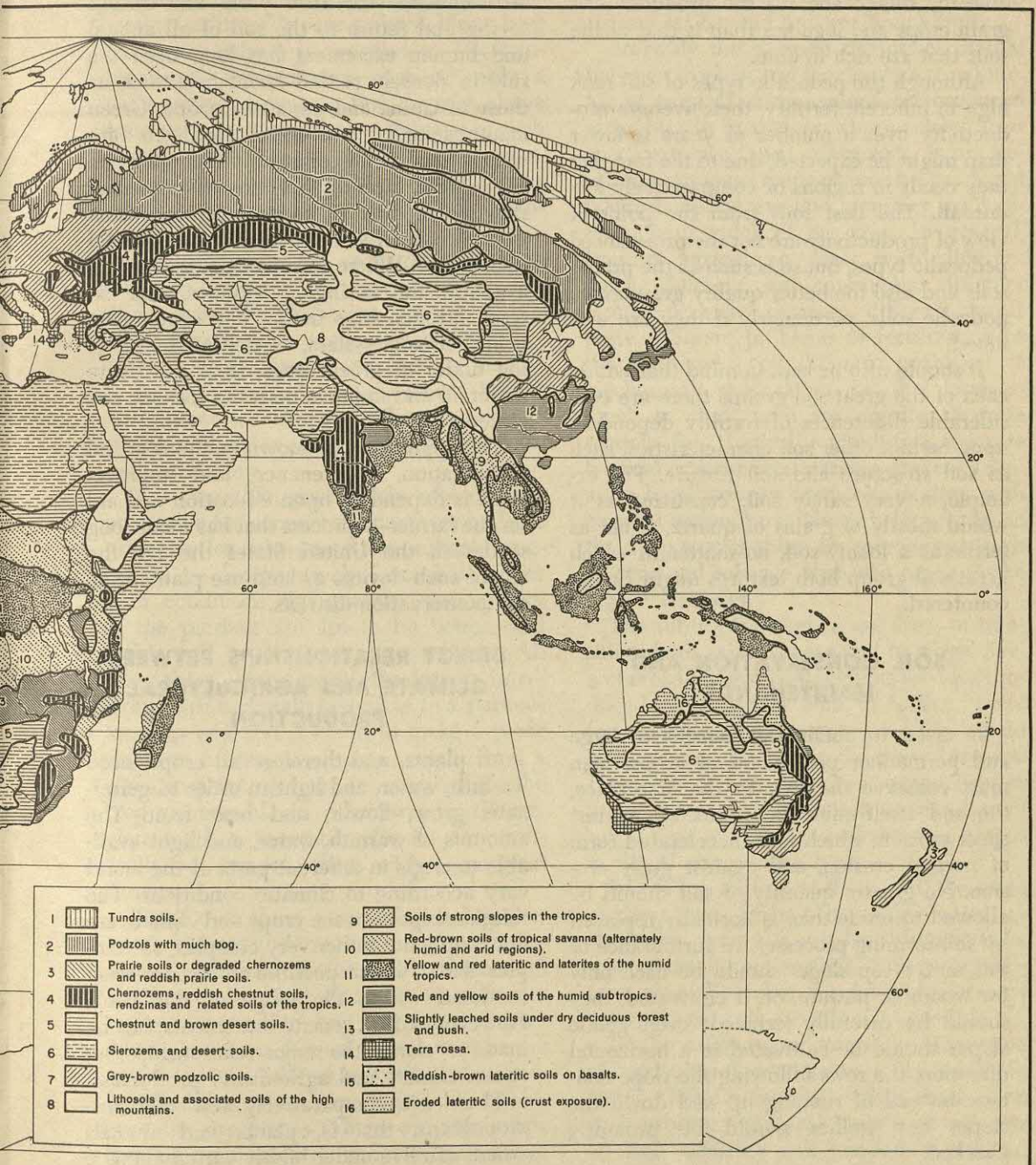


Fig. 65. A generalized map of the major soil regions of the world.


1 Tundra soils.
2 Podzols with much bog.
3 Prairie soils or degraded chernozems and reddish prairie soils.
4 Chernozems, reddish chestnut soils, rendzinas and related soils of the tropics.
5 Chestnut and brown desert soils.
6 Sierozems and desert soils.
7 Grey-brown podzolic soils.
8 Lithosols and associated soils of the high mountains.
9 Soils of strong slopes in the tropics.
10 Red-brown soils of tropical savanna (alternately humid and arid regions).
11 Yellow and red lateritic and laterites of the humid tropics.
12 Red and yellow soils of the humid subtropics.
13 Slightly leached soils under dry deciduous forest and bush.
14 Terra rossa.
15 Reddish-brown lateritic soils on basalts.
16 Eroded lateritic soils (crust exposure).

able for tillage and for the production of grain crops and legumes than is that of the soils that are rich in lime.

Although the pedocalic types of soil rank high in inherent fertility, their average productivity over a number of years is lower than might be expected, due to the fact that they occur in regions of comparatively low rainfall. The best soils from the point of view of productivity are not the pronounced pedocalic types, but soils such as the prairie soils and also the better quality gray-brown podzolic soils, particularly if they are well limed.

It should also be kept in mind that within each of the great soil groups there are considerable differences of fertility depending upon certain other soil characteristics, such as soil structure and soil texture. For example, a very sandy soil, consisting as it would mostly of grains of quartz, is not as fertile as a loamy soil, no matter in which great soil group both textures might be encountered.

SOIL CONSERVATION AND MAINTENANCE

In order to obtain the benefits of large and permanent production of crops, man must conserve the soil. In the first place, the soil itself must be protected against sheet erosion, which is an accelerated form of normal erosion, and against gully erosion. No greater quantity of soil should be allowed to erode than is normally replaced by soil-forming processes. In furtherance of this aim, steep slopes should be used only for woods or pasture, or, if cultivated, they should be carefully terraced; even gentle slopes should be cultivated in a horizontal direction, the rows following the slope contour instead of running up and down the slope; any gullies should be promptly checked.

Even when the soil is kept in place by such means, and in flat-lying soils not subject to erosion, there is need for soil maintenance—the preservation and further improvement of soil fertility. Any soil, except that annually replenished by natural floods, will eventually decline in fertility if crops are removed year after year. The careful saving and return to the soil of all animal and human excrement has long been the rule in densely settled farmlands, such as those in China and parts of Europe. Green manures and commercial fertilizers are widely used in all countries which carry on commercial farming. Rotation of crops may slow up the loss of certain elements from the soil, which so often results in chemical unbalance. Where insufficient manure is available the raising of legumes, that extract nitrogen from the air and accumulate it in their root system, as well as the plowing under of green crops, help greatly to maintain and improve both the fertility and structure of the soil.

The application of known methods of soil conservation, maintenance, and improvement is dependent upon education and aid for the farmer—a process that has made long strides in the United States through the use of such devices as land-use planning in soil conservation districts.

DIRECT RELATIONSHIPS BETWEEN CLIMATE AND AGRICULTURAL PRODUCTION

All plants, and therefore all crops, need warmth, water, and light in order to germinate, grow, flower, and bear fruit. The amounts of warmth, water, and light available to crops in different parts of the world vary according to climatic conditions. The relationships between crops and climate are not simple but rather very complex, so complex that it is not possible to discuss them in detail within the scope of this book. However, a few general statements can be made to clarify the major relationships between climate and agricultural production.

There are comparatively few real *cosmopolitans,* that is, plants and animals which can live under highly varied climatic conditions. The dog, the companion of man in the deep tropics as well as in the high arctic, is probably the best example of a cosmopolitan. On the other hand, Guernsey or Frisian-Holstein cattle can flourish neither in regions of steppe or desert climate nor in those of tropical rainy climate.

Among crops the dependence upon climatic conditions is even greater. Many crop plants are extremely sensitive to low temperatures. Temperatures that for only a short period drop to a few degrees above freezing point may do great damage to such plants as the banana and the cacao tree. Other crops, such as winter rye or winter wheat, may be able to successfully withstand temperatures that remain well below the freezing point for weeks on end. Some crops do not show any appreciable growth at average daily temperatures below 60°F., while others grow vigorously at temperatures of 40°F. Some crops, such as manioc or Hevea rubber, do well in warm, humid environments, whereas others, such as wheat and oats, could not survive under such conditions.

It is desirable, particularly where crops are grown for commercial purposes and not primarily for subsistence, that climatic conditions be comparatively favorable. Under such conditions the quantity and quality of the product are apt to be better, and yields will tend to be more reliable. All other things being equal, the farmer in regions with a climate favorable to a particular crop will find it easier to make a profit than the farmer in an area which, from a climatic point of view, is marginal for the crop concerned. In other words, the regions with a favorable climate can ordinarily out-compete those with a marginal climate.

Because of these basic relationships between climate and crops, it is logical to discuss agricultural products of commercial importance in connection with the climatic regions where they are of greatest importance. Of course, it must be admitted at the outset that no scheme of treatment is perfect, and that any scheme must make allowance for exceptions. There are few crops that are rigorously limited to one particular type of climate. In addition, as has been mentioned earlier, the physical factors are not the only ones that influence the geographic distribution of crops. Thus rice has been carried far north by the Chinese and Japanese, who have a particular predilection for this food, and the grapevine may be cultivated under marginal conditions in regions far beyond its commercial limit.

Probably the sharpest distinction is that between tropical and temperate agriculture. Many tropical crops cannot be produced satisfactorily in regions where winter frost is a certainty, and, conversely, many so-called temperate crops cannot be produced where temperatures and humidity are high throughout much of the year. In general, tropical agriculture deals with different crops, different soil conditions, different fungus or virus diseases, different insect pests, different problems of fertilization of the soil, and even different problems of mechanical preparation of the land—so much so that there are usually separate schools for tropical agriculture, separate tropical experimental stations, and even separate handbooks or textbooks dealing with tropical agriculture. Nevertheless, even in the deep tropics there are some crops, such as corn and tobacco, that also occur in the higher latitudes.

The subtropical regions are areas of transition, both as to climate and to crops. Several crops are grown there that are also produced either farther south or farther north, for example, rice is grown in the humid subtropics and wheat in the dry subtropics. However, certain crops are outstanding in these areas, such as cotton in the humid subtropical climate and olives and grapes in the Mediterranean type.

In the dry regions of the world, the areas of steppe and desert climate, the entire agricultural picture is usually different from that in the humid regions. Tillage agriculture generally takes second place, except where large-scale irrigation is possible.

In the following chapters the discussion of agricultural production is based upon major climatic regions, rather than upon such arbitrary physical units as continents or such arbitrary and temporary political units as countries. A discussion, product by product, unless very detailed, would be apt to neglect the basic geographic setting which is so important for the understanding of crop and livestock production, and would entail many repetitious statements pertaining to climatic and other physical factors.

SELECTED GENERAL REFERENCES FOR CHAPTER 7 AND FOR CHAPTERS 8 TO 15

Up-to-date statistical information on the production of and trade in agricultural products in the United States, and to some extent elsewhere in the world, will be found in: *Agricultural Statistics*, published by the United States Department of Agriculture, Washington, D.C., U.S.A. This is an annual publication.

Statistical data on production and trade by countries can be found in: *Production Yearbook*, of the Food and Agriculture Organization of the United Nations, Rome, Italy, and in the *Trade Yearbook* of the same organization. These volumes usually appear with a 1 to 1½ year delay.

For detailed information on the United States, see the volumes of the Agricultural Censuses, published by the Bureau of the Census, United States Department of Commerce, Washington, D.C., U.S.A.

Also: A Graphic Summary of Land Utilization, United States Census of Agriculture: 1959; and, Final Report, Vol. V, Part 6, Chapter 1, Special Reports, Washington, D.C., 1962, 48 pp. This report contains many maps showing crop distribution in the United States.

Almost all modern countries publish statistical data pertaining to crop acreage, crop production, livestock, and trade in agricultural products. Many do so annually, others at intervals. In the United States many such publications are available, for example, in the Library of Congress and the Library of the Department of Agriculture, Washington, D.C., and in the New York Public Library.

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8

The Regions of Humid Tropical Climates

characteristics of the three types

DURING A cold winter in the middle latitudes many people will look with envy at advertisements showing white tropical beaches and waving palm fronds. The desire is great to leave the marked temperature changes, sleet, and snow of northern climates behind and seek the always equable climate of the tropical lands. Unfortunately, spending a brief period at a tropical luxury resort is something quite different from living in the tropics, month after month, year after year, and in areas which lack the special physical environment and other advantages that resorts must have. Thus a man from farther north who loathed winter may come to long for it, and one who wanted even temperatures may wish for the quick invigorating changes of the middle latitudes.

The humid tropical climates are characterized by year-round warmth. Frost does not occur, except in some high mountain areas, such as the high Andes of western South America, the Ruwenzori massive (located near the equator in Africa), and the volcanoes of Java. Rainfall conditions differ greatly. Some areas, though humid part of the year, have one, or even two, dry seasons, when the land may even take on a parched aspect. In the more humid regions there is year-round precipitation, no dry season, and no cold season. Here plant life is active throughout the year. Vegetation is luxuriant, and insects and microorganisms abound.

The continual warmth and frequent dampness of the humid tropical climates pose problems of physiological adjustment to human beings, regardless of race, although some groups apparently adjust more easily than others. Other serious problems are caused by the fact that many of the insects and microorganisms there bring diseases of one sort or another to man, to his domestic animals, and to his crops; many of these diseases are so different from those in the cooler climates that, insofar as man is concerned, tropical medicine is thought of as being distinct from that practiced in the middle latitudes. The problems of fighting plant and animal diseases are also different, as are even those of growing crops

and raising animals. There are handbooks and schools of tropical agriculture in contradistinction to those dealing with the agriculture of the middle latitudes.

That man is greatly affected physically by his climatic environment is beyond question. For example, the temperature of the inner parts of the body is about 99°F., while that of the skin is 92°F. Thus, the body loses heat to the skin, and if the outside temperature is below 92°F. the skin loses heat to the atmosphere. This loss of heat is necessary, as the body, even when at rest, continues to generate heat to an approximate amount of 80 kilogram-calories per hour. Without loss of heat, overheating would follow, resulting in collapse and death. Normally, when outside temperatures are considerably lower than 92°F., man loses a great deal of heat if not clothed. Heat is lost through the necessary warming of food, drink, and air intake, and through the evaporation of water in respiration, but on the average as much as 80 per cent of the heat loss is through the skin, by radiation, convection, and evaporation of sweat.

Thus it may be seen that the necessary heat loss takes place most easily in regions of cold and cool climates, and fairly easily in warm regions with low humidity where evaporation rates are high. In fact, in cold weather, even when man is working hard and thus is generating extra calories of heat, excessive heat loss must be prevented by suitable clothing. In very cold weather heat-generating physical activity becomes essential in order to prevent excessive heat loss, no matter how heavy the clothing is.

In warm, moist climates it becomes more difficult to lose the necessary amount of heat, especially when much heat is generated as a result of arduous physical activity. Losses through radiation are lower, and the losses through convection and through evaporation of sweat are greatly reduced, when the relative humidity of the surrounding air is high and there is little air movement. Thus in the humid tropics, even though man may be but partly clothed, extra body heat developed by muscular activity becomes disagreeable and even dangerous, much sooner than in areas of cool climate because the excess can often be lost only through more copious perspiration.

It does not seem strange, then, that man is generally less energetic in the humid tropics than in the cooler and colder middle and high latitudes.

The humid tropical climates form a broad equatorial belt around the earth, extending beyond the Tropics of Cancer and Capricorn in some areas and not quite reaching them in others. (See World Map of Climatic Regions, and Fig. 66). As to their general characteristics, there are two commonly held notions which should be dispelled—that they are excessively hot, and that they are always rainy. Contrary to popular belief, temperatures usually are not excessively high. Higher temperatures occur in summer in interior United States than are ever encountered in most places near the equator. On the other hand, there is no cold period in the humid tropical climates. The roles of summer and winter in the higher latitudes are often taken over by pronounced wet and dry seasons. The dry season may be so pronounced that it causes general leaf fall and even cessation of ordinary agricultural activities. The dry margins of the areas of savanna climate may even be classed as subhumid because of the long duration of the dry season.

On the whole, the greatest amount of annual rainfall occurs in the equatorial belt, from where it decreases both northward and southward. But even where in the equatorial belt the rainfall exceeds 100 inches, most of it comes as heavy showers, often in late afternoon or at night, while brilliant sunshine prevails during most of the day. This is an important factor in accounting for the rapid growth of vegetation in such areas. The equatorial phases of the tropical climates are often rainy, warm and humid month after month, a condition that proves quite enervating, particularly to people who are accustomed to the invigorating influences induced by quick changes from warm to cool or cold.

Within the belt of humid tropical climates three major climatic types may be recognized, each extending over large areas. These are: (1) the tropical rainy type

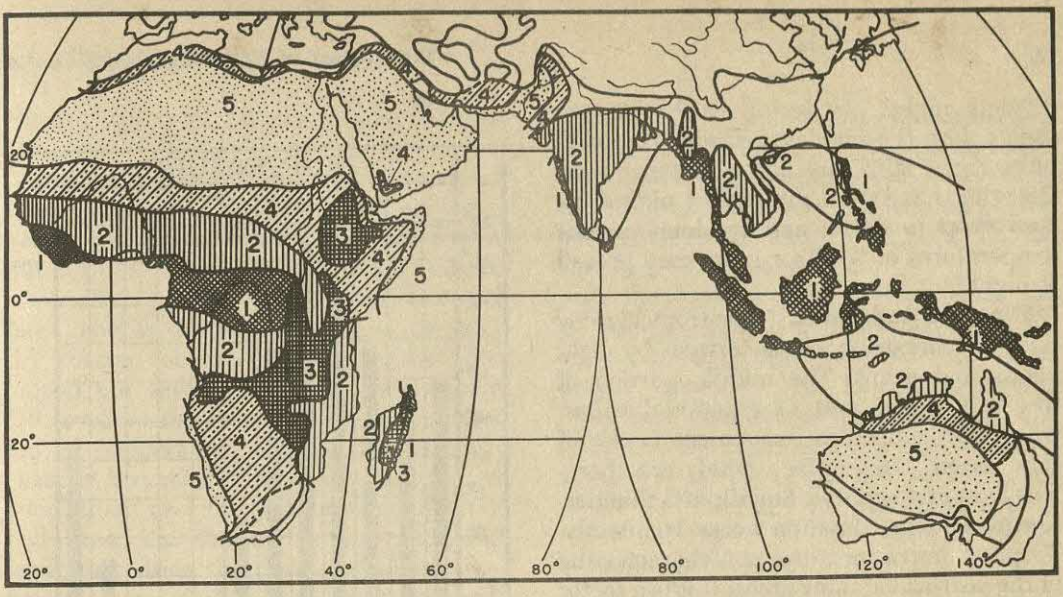


Fig. 66. Regions of tropical climate in the Old World: 1. Tropical rainy type. 2. Tropical savanna type. 3. Tropical highland type. 4. Tropical steppe type. 5. Warm desert type.

(areas marked 1 on the climatic map), where all the months are warm and rainy without a pronounced dry season, and where the diurnal and annual ranges of temperature are slight; (2) the tropical savanna type (areas marked 2 on the climatic map), where there are pronounced wet and dry seasons, and a somewhat greater annual temperature range—this type sometimes is subhumid in character; (3) the tropical highland type (areas marked 3 on the climatic map), with year-round warmth but somewhat lower average temperatures, and small annual but marked diurnal range of temperature.

THE TROPICAL RAINY TYPE OF CLIMATE

(Areas marked 1 on World Map of Climatic Regions and Fig. 66.) The principal characteristic that distinguishes the tropical rainy from the other types of tropical climates is the absence of a pronounced dry season. In general, regions having this type of climate are located in the equatorial belt, ranging a few degrees north and south of the equator. The three major regions that come under this classification are: (1) much of the Australasian archipelago and the adjacent portions of Asia, (2) part of the Congo basin and Guinea coast of Africa, and (3) the Amazon lowland and Guiana coastal region of South America. All owe their climatic characteristics chiefly to their location near the equator. Here, annual insolation is highest, the heated, expanded, moisture-laden air rises, and adiabatic cooling produces heavy precipitation.

Smaller areas with essentially the same type of climate occur along tropical east coasts where the trade winds, blowing onto shore from warm oceans, are forced to ascend mountains or plateaus, causing heavy orographic rainfall, as in Brazil, the West Indies, Central America, and eastern Madagascar. In southeastern Asia such strips of high orographic rainfall are caused both by the trade winds and by monsoon winds. In some instances coastal lowlands up to 1,000 feet are desertlike, while the higher slopes are drenched with rain. This is notably true along the north coast of Venezuela.

Temperature characteristics. The temperatures are not exceptionally high, averaging generally about 75° to 85°F. Monotony is the dominant feature. The difference between the average temperatures of the warmest and the coolest month rarely exceeds 5°F., and in some cases is only about 2°F. The diurnal range is ordinarily greater than the annual range, but in some

districts nights are less than 10 degrees cooler than the midday periods. Temperatures above 90°F. are not common, but on the other hand even the coolest nights seldom drop to 60°F., and for long periods temperatures of 75°F. or more may prevail at night.

Pressure and winds. The tropical rainy type of climate is characterized by light winds and calms. The middle portion of this belt is the area of equatorial calms, where the general air movement is one of slow ascent, and surface winds are therefore light and variable. Squalls and thunderstorms of short duration occur frequently. Tropical hurricanes are not characteristic of the year-round rainy areas; this is a factor of great economic significance for tropical commercial agriculture.

Rainfall and humidity. Relative humidity is generally high. In many areas it averages 80 per cent or more, and periods of 90 per cent are not uncommon. The total annual rainfall is ordinarily in excess of 60 inches, and some places have 150 to 200 inches a year. The rain comes at fairly regular hours during the day, mostly as heavy showers which last but a short time and are succeeded by brilliant, almost dazzling sunshine. The more prolonged rains occur at night, but the latter part of the night is not rainy, and the morning hours are usually clear. Even where the rainfall is heavy the percentage of sunshine is high; this combination of abundance of rain, much sunshine, and persistent warmth promotes the dense growth of vegetation so characteristic of areas with this type of climate. In Singapore (as may be seen from Fig. 67) average temperatures are close to 80°F practically all year long. This even march of temperature is caused partly by the fact that the city is almost entirely surrounded by water bodies. Also, the variation in monthly rainfall is small. In French Guiana (Fig. 68) the temperature march is not very different from that of Singapore, but the rainfall distribution shows distinct seasonality. However, the dry season, in September and October, is brief, and the rainfall during the largest part of the year is so high that the

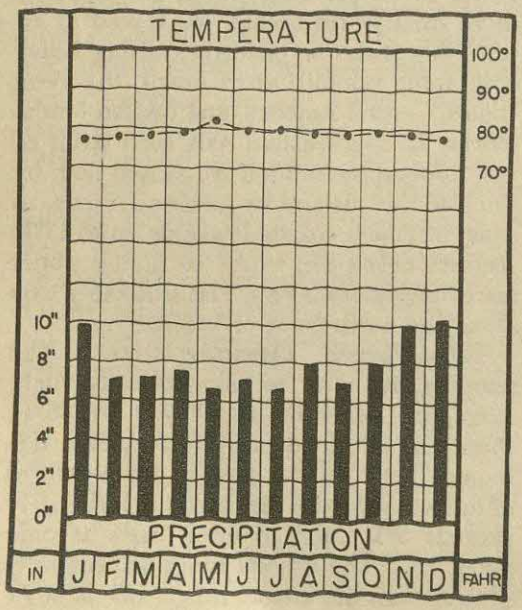


Fig. 67. Tropical rainy climate. Average temperature and precipitation, Singapore. Altitude 15 feet, total precipitation 95 inches.

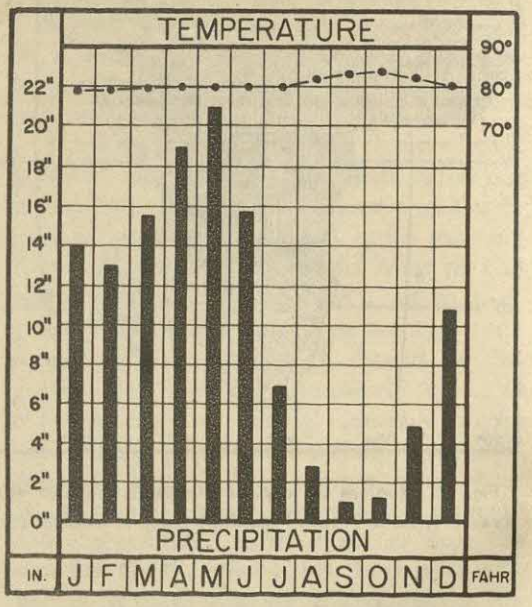


Fig. 68. Tropical rainy climate. Average temperature and precipitation, Cayenne, French Guiana. Altitude 18 feet, total precipitation 126 inches.

climate still is in essence a rainy tropical climate.

The outstanding features of the tropical rainy climate may be summarized as: winds gentle, temperatures warm and monotonous but not hot, and rainfall abundant, varying seasonally and from year to year, but with most months quite rainy. Where so-called dry seasons occur, they are neither prolonged nor severe, and some rain usually falls even in the driest month. The monotony of temperature and the lack of sharp changes become tiresome, especially to the white man, and the difficulty of adequate body heat loss during the warmest hours tends to reduce the desire of all people—white, brown or black—to work zealously and at high speed. "Eternal summer" sounds delightful, but in the long run the even temperatures of the tropics are not so pleasant as the ever-changing temperatures of the middle latitudes. The variable weather of the middle latitudes is invigorating, the eternal summer of the tropics is enervating.

Native plant and animal life. The climatic conditions just described quite naturally result in a luxuriant growth of vegetation, varying from rain forest, where the tree growth is so dense as to leave but little opportunity for underbrush, to the tropical jungle, with its maze of trees, shrubs, and vines. Such dense, jungle-type forest often establishes itself where the rain forest has been cut by man, and where, after use, the land has been abandoned.

In the tropical rainy regions there are no common periods of flowering and fruitage for all the vegetation, and there is no distinct seasonal leaf fall. Broad-leaved evergreens characterize the landscape. The forest consists of a mixture of a bewildering number of species, quite in contrast to the stands with one or a few dominant species which are typical of the forests of higher latitudes. (See Figs. 69, 70, 71.)

The following quotation gives an excellent idea of the impression that the tropical forest makes upon one accustomed to the northern woods.

> In New England one walks quite gradually into a wood, but not so in the jungle. One steps through the wall of the tropic forest as Alice stepped through the looking glass; a few steps, and the wall closes behind. The first impression is of the dark, soft atmosphere, an atmosphere which might be described as 'hanging,' for in the great tangle of leaves and fronds and boles it is difficult to perceive any one plant as

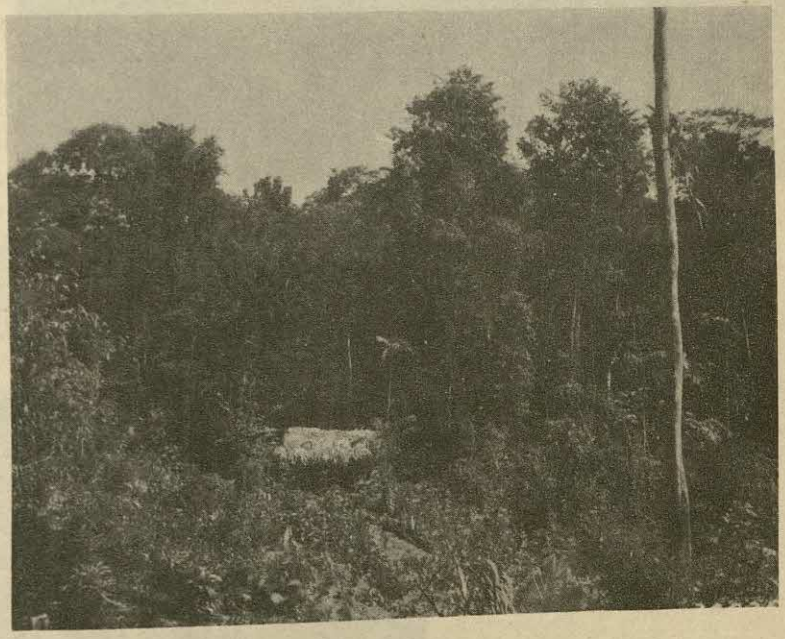


Fig. 69. Jungle-type vegetation in the Arena Forest Reserve, Trinidad. This stand contains several valuable timber species.

Courtesy U.S. Forest Service

a unit; there are only these hanging shapes draped by lianas in the heavy air, as if they had lost contact with the earth. And this feeling is increased by the character of the earth itself, which is quite unlike the thrifty woodland floor at home; here the tree boles erupt out of heaped-up masses of decay, as if the ground might be almost any distance beneath. The trees themselves are so tumultuous and strange that one sees them as a totality, a cumulative effect, scarcely noticing details; there is a strange, evilly spined palm trunk, though, and a crouching plant with gigantic fronds, and a fantastic parasite, like a bundle of long red pipe-cleaners studded with olive nuts, fastened here and there to the high branches, and the looming trunk of a silk-cotton, seen only when one is right on top of it; it soars off through the leathery green canopy overhead.

The forest increases in stature, it seems, as we ascend the river. . . . In the river the floating debris is increasing, littering great areas of the expanse, but it is the jungle which changes most. A number of trees I have not noticed before, and especially one with a smooth purple-mahogany trunk—I'm told this is the purpleheart. The larger trees have aerial gardens of red-flowered epiphytes, *Bromelia*, and strange silver cylinders—these are hornets' nests—hanging like Christmas ornaments; everywhere, fastened leechlike to the trunks, are the dark masses of white ants' nests. The lowest branches of these trees must be fifty feet from the ground; in the evening light, its pale marble columns



Fig. 70. This is what the great Amazon tropical rainforest or "selva" looks like from the air: a forest cover unbroken for miles and miles. The trees are mostly tall to very tall. Some of the latter stand out as somewhat lighter spots in the photograph as they rise above the general level of the canopy.

Courtesy Conselho Nacional de Geografia, Brazil



Fig. 71. The tropical rainforest as seen from the Amazon river, Brazil. Along the river the trees are not as tall as farther inland, although here one tree (Ceiba pentandra) stands out.

Courtesy Conselho Nacional de Geografia, Brazil

mysterious in the greens, the forest is truly beautiful; it is difficult to conceive of a lovelier forest in the world.[1]

Since dense vegetation dominates the land, much of the animal life has adapted itself to living in the trees. The fauna includes numerous flying or climbing types—such as monkeys, snakes, birds, and insects—and there are few strictly ground-dwelling species and almost no burrowers. The birds and insects are characterized by brilliant, even gaudy, colors, among which reds, blues, and greens are the most common. The streams harbor reptiles and mammals as well as many species of fish. Here is the home of the alligator, the crocodile, and, in Africa, the hippopotamus. Abundance of vegetation ordinarily fosters abundant and varied animal life, but the dense greenery furnishes such admirable hiding places that an uninitiated traveler is likely to see little evidence of the numerous animals. Thus the stranger in the tropical forest is led to believe that the uncanny silence in which he finds himself is indicative of a scarcity of animal life, while as a matter of fact his every movement is being watched by many eyes.

The soils of the rainy tropics. In the humid, warm tropics, where average temperatures are over 78°F., the destruction of humus material tends to be faster than its formation. Thus tropical soils are often short in nitrogen, especially after the cutting of the forest, which is the main supplier of humus. Owing to heavy precipitation and relatively high temperatures throughout the year, the soils are subject to continual and vigorous leaching. The low content in humus substances further increases the ease with which the plant salts can be removed. Besides washing out plant nutrients, the leaching processes, as a result of combined high soil moisture and warmth, also tend to remove the silica of the silicate minerals. If the process goes far enough, little may be left but an infertile mixture of aluminium hydroxides and iron hydroxides, with a thin top layer carrying a slight admixture of humus. These processes of intense leaching are characteristic of all regions of humid tropical climates and are different from the processes that take place in the soils of the middle latitudes. They lead to the formation of various types of lateritic soils, even of pure *laterite,* the infertile mixture referred to above. While laterite probably ranks as the poorest soil in the world, the lateritic soils, in which the processes of leaching have not yet reached the final phase, are usually deficient in many or all of the essential plant foods and often have poor physical structure.

The color of the lateritic soils in the rainy tropics is generally yellowish to reddish brown in their upper horizon, except for a thin layer at the top colored dark by humus. Below this follows at varying depths a dark ochre-yellow or mottled yellow and red horizon, which is rich in iron and quite compact. Farther down follows a still harder horizon where the material has been cemented by silicates washed in from above. Usually these soils are heavy, and they become hard and compact upon drying. In a few cases it is necessary to use dynamite in order to break them up for proper aeration. Great care must be taken not to plow or otherwise stir them when they are too wet.

Some real laterites are found on old, badly leached upland areas in the tropics, such as in parts of Borneo and Sumatra; in the interior of Africa, as in the Sudan; along the Guinea coast; in parts of the Amazon basin; and in the Guianas. Fortunately, true laterites, though widely scattered, are not of large extent.

In general, tropical soils are not as fertile as described by some writers, who were impressed by the luxuriant natural vegetation or whose observations were limited to the soils of the young alluvial deposits bordering the streams. On the contrary, most tropical soils are decidedly poor; liberal applications of fertilizer are needed, and careful methods of tillage must be employed if productivity is to be maintained for more than three or four years after the clearing of the virgin forest.

In the tropical rainy regions there are, however, two general groups of highly productive soils: (1) the young upland soils

[1] Peter Matthiessen, *The Cloud Forest,* New York: The Viking Press, Inc., 1961.

that have resulted from the rapid weathering of recent lavas of low acidity, and (2) the alluvial soils that have developed upon materials deposited along the stream courses or upon materials that have been washed down from mountains and deposited as alluvial fans which in some cases merge into piedmont plains. Java and the rainy slopes of the Hawaiian Islands are well-known examples of areas of young volcanic soils; and the east coast of Central America, the famous banana land, is an illustration of a region of fertile alluvial soils. In both Java and Hawaii recent volcanics, with varied mineral content but of low acidity, weather so rapidly that agriculture is favored by an unceasing liberation of soluble salts. Such lands produce abundantly, whereas older soils, similarly tilled, give small returns.

Agriculture. The climate, the dense forest, and the generally poor soils are the most important environmental factors in retarding agricultural development in the tropical rainy regions of the world. Tropical forest areas are difficult to clear; trees are large, much brush must be chopped out, and unless constant vigilance is practiced, the latter soon reclaims the land because of its vigorous, incessant growth.

Although the virgin soil may be productive, the fertility is not such as to give large yields for an extended period of years. The rapid decline in productivity of the land is due primarily to the depletion of the humus content of the A horizon, the decline in the amount of available nitrogen, and the accompanying speeding up of the leaching of other plant nutrients. Often there is also considerable loss through soil erosion. In native agriculture the decline is so rapid and severe that in most places lands are abandoned after two to seven years of farming. New lands are then cleared, and the old ones permitted to revert to brush and jungle. This seminomadic type of tillage agriculture, often referred to as the *milpa system* after conditions existing in Yucatan, occurs over large areas in the tropics. In Africa particularly this system adversely affects soil conditions and forest conditions in many sections. Cattle are absent or scarce in many of the tropical rainy regions for reasons of disease, and thus as a rule manure is not available. The native has little knowledge of green manures, and he usually lacks the money to buy the considerable quantities of mineral fertilizer that would be necessary to maintain the fertility of the soil, particularly if he produces for home consumption only and not for the world market. Modern pedologic studies in Indonesia, Malaya, the Congo region, and elsewhere have shown conclusively that, regardless of luxuriant stands of forest, most soils of the rainy tropics are poor rather than rich. Maintenance of soil fertility and increase in soil fertility are problems that will require a great deal of scientific study, in regard to what is physically as well as economically possible. This is particularly true since many of the tried and tested methods of middle latitude agriculture are not applicable in the tropics.

In the tropical rainy regions the greatest densities of rural population frequently coincide with regions of recent volcanic activity, where decomposition of basic ash and lavas occurs rapidly, and where these volcanic materials are so young that leaching has not yet succeeded in impoverishing the soils. This is well illustrated in Java, Costa Rica, and Salvador. A still more striking example is the island of Sumatra, where population is dense on the volcanic soils in some of the highland areas, and where on the volcanic soils of Deli was established one of the major areas of modern tropical plantation industry in the world. By far the largest part of the lowland area of eastern Sumatra, however, is sparsely populated, and, except along the streams, the soils are so poor that the area has a limited agricultural future.

Among other handicaps facing tropical agriculture is the prevalence of plant and animal pests and diseases. Warm, humid climates with a total absence of frost are conducive not only to an abundance of insect life, but also to the development of fungi and all sorts of microorganisms. Commercial plantations of various kinds have been ruined because of the attack of some disease against which the scientist has proved powerless. The plantations of "Arabian"

coffee (*Coffea arabica*) in Ceylon and Indonesia were completely destroyed at the end of the nineteenth century by a fungus, *Hemileia vastatrix*, and only replacement with hardy but less valuable *robusta* varieties saved the industry. The cacao plantations of Ecuador have been heavily damaged by the dreaded witches'-broom disease. Entire districts in parts of Central America have had to abandon banana production because of the ravages of the *Sigitoka* disease. Furthermore, fungi and insects quickly attack stored products unless precautionary measures, nearly always expensive, are rigorously carried out. Many tropical products are highly perishable and must be marketed promptly to avoid deterioration; hence, longtime storage and orderly sale in response to market demands, such as characterize the marketing of grain crops in the middle latitudes, are imposisble. Conditions favorable to insects and microorganisms result also in a high disease rate among all kinds of livestock. In large parts of Africa the occurrence of the tsetse fly precludes the keeping of any livestock whatsoever (Fig. 72). Dairy cattle such as are kept in the middle latitudes do not flourish in the rainy tropics and generally cannot be kept economically. Cattle must be resistant

Fig. 72. Distribution of Glossina palpalis and Glossina morsitans (tsetse flies), carriers of the germs that cause sleeping sickness. In areas infested by tsetse flies it is impossible to keep any domestic animals, due to the ravages of the disease. (After W. Frantzen, "Matériaux pour l'étude des calamités," No. 16, Geneva, 1928.)

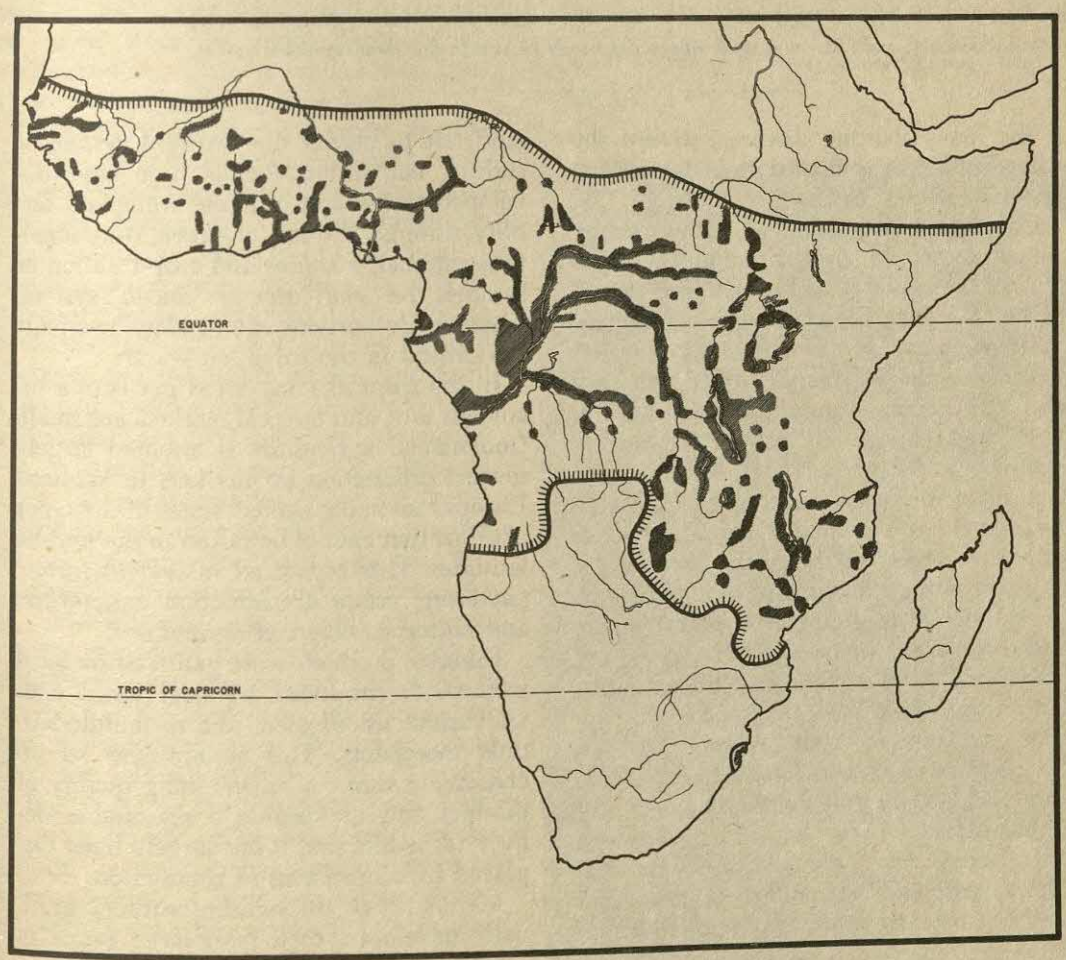




Photo by Walter Deshler

Fig. 73. Typical patch agriculture in the tropics, in an area of "milpa" type farming. Not all the trees are cut. Some of the patches are in cultivation, others are in fallow. WaKamba area, east of Kenya highlands, Africa. A small village can barely be seen in the lower righthand corner.

to the many existing diseases, as are the water buffalo of southeastern Asia and the Brahma cattle of India.

Subsistence agriculture as carried on by the native peoples is primitive and often of the patch-farming or milpa type mentioned above (Fig. 73). Clearings usually are comparatively small, but as they can be farmed for only a limited number of years, new lands are needed constantly. Since in any given area usually only part of the land is suitable for tillage purposes, it is evident that under this system, carrying capacity of the land per square mile is low. Thus population over most of the areas is relatively sparse, and the standards of living are low. Grains such as sorghum, corn, and dry rice, also roots, fruits, nuts, and game are chief features of the diet. Fish may be available, but on the whole the intake of animal proteins and fats is small. Where soils are richer and local population has become dense, as in the fertile delta lands of southeastern Asia, the areas of young volcanism of Indonesia, and a few sections of tropical Africa, sedentary agriculture is practiced. In these areas there usually is not sufficient land left to permit the wasteful system of shifting cultivation. People here have developed techniques of maintaining soil fertility through the use of green, and sometimes animal, manures and crop rotation or through the *"padi" rice* or *"sawah"* system, where large portions of the plant nutrients are carried in the irrigation water.

In the tropical rainy areas per capita income is low, and internal markets are small. Commercial agriculture is oriented largely toward production for markets in Western Europe and in the United States of the types of crops that cannot be raised in the middle latitudes. It is organized in several forms: *gathering*, *estate* or *plantation agriculture*, and *native commercial agriculture*.

Initially, products were gathered by local workers or produced on local farms and, via various middlemen, sold to middle-latitude merchants. This system was so inefficient in terms of maintaining quality of product and of keeping a reasonable delivery schedule that it has largely been displaced by other forms of production.

Merchants of the middle latitudes gradually developed their own large farms in

the tropics. These are called "estates" or "plantations." In the United States it is probably better to speak of tropical estate than of tropical plantation agriculture, as the term plantation inevitably calls to mind the ante-bellum Southern plantation. The latter had little in common with the modern tropical estate, as it essentially involved rather primitive and inefficient methods of production, nonwage labor, and little or no contact with scientific research. Estate agriculture, on the other hand, is a form of large-scale modern agriculture, which necessitates heavy capital investment for machinery and equipment, which keeps in close touch with modern scientific developments, and which specializes in products for the world market, such as sugar, bananas, tea, cacao, and rubber. Under the estate system of production the enterprise usually is incorporated, and the management is in the hands of and under the control of people and capital from the middle latitudes, although Indian, Chinese and other non-Western management is increasing.

While practices differ with crops and districts, the procedures followed in establishing agricultural plantations in tropical lands show much similarity. The steps taken are usually about as follows: (1) the land is investigated carefully as to soils, slopes, drainage, forest cover, and local climatic conditions; (2) the land selected is then surveyed, and the location, size, and form of the field units are determined; (3) farm headquarters are established, and the necessary construction program is inaugurated to provide water supplies, living accommodations for the white employees and native laborers, pastures for draft animals, and warehouses for materials and supplies; (4) the underbrush is cleared with machetes, axes, or, nowadays, frequently with modern earth-moving machinery, and the slash is burned; (5) the large trees are felled, and some of the logs are used for timber, while others are left where they fall; (6) roads are built to serve the individual farm units, and often tramways are extended into the fields to be used in hauling out the harvested products; (7) in some cases drainage ditches must be constructed, in others, it is necessary to build a system of irrigation, and in still other instances both drainage and irrigation must be provided to take care of heavy floods during wet seasons and droughts during dry seasons, either of which may prove disastrous to the growing crops (Fig. 74).

The most efficient use of the lands of the humid tropics involves scientific practices of a high order. In addition to the steps outlined, it is usually necessary for the plantation owners to provide medical and hospital services, school facilities, and recreation centers. Economic welfare is dependent upon the maintenance of a community wherein management officials and labor are healthy, energetic, and content. Facilities to promote such results involve expense, but general experience indicates that the outlays are economically as well as humanely sound.

Fig. 74. Spraying the trees against disease on a modern banana plantation.

Courtesy United Fruit Co.



Over the past two decades native production of agricultural products for export has increased greatly in importance. This is not native agriculture in the traditional, casual sense. The farmers who produce for export often receive technical aid from agricultural extension services and marketing aid from cooperative or government marketing boards. The technical aid fosters efficient production of crops acceptable to world markets, while the marketing boards inspect the product to insure quality and thus build up and maintain the reputation of the producing area. In most cases they also serve to stabilize the price paid to the native producer and to enable him to earn a higher price than would be possible if he were at the mercy of local middlemen. With these aids, native production has tended to make inroads on estate production in those cases where the product is simple to grow, harvest, and process. Cacao and rubber are typical cases in point. However, when production involves difficult growing conditions or the necessity of growing on a large scale or when harvesting, processing, or transportation pose technical problems for the solution of which considerable capital is required, as in the case of sugar or bananas, the estate system, with its greater technical efficiency, tends to predominate.

THE TROPICAL SAVANNA TYPE OF CLIMATE

(Areas marked 2 on World Map of Climatic Regions and Fig. 66.) The tropical savanna type of climate has a long rainy season, often with a double maximum, and a short but pronounced dry season. This distinctly seasonal distribution of rainfall is the chief difference between the savanna and the tropical rainy type, although usually the savanna also has a smaller total amount of precipitation. A difference of lesser consequence is the slightly greater seasonal temperature range resulting from the higher latitudes of the savanna areas. Toward the outer margins the dry season may become so long and pronounced that the climate is distinctly subhumid.

The map of Climates of the World, at the end of book, shows that the tropical savanna climate is more extensive than any other type of tropical climate. On the whole, it occurs north and south of the tropical rainy areas, extending 10 or more degrees of latitude beyond them on either side, thus marking the first stage in the gradual transition from rainy to dry. Thus in Africa this type of climate flanks the tropical rainy region on both sides, from the Atlantic Ocean to the Lake Plateaus of the interior. In Australasia it occurs in southeastern Indonesia and northern Australia, as a transition belt between the rainy tropics and the drier climates of Australia. To the northwest, in India and in the Farther India peninsula, it marks the transition to the drier climates of interior Asia and the Near East. In South America it again flanks the rainy tropical Amazon area, although farther north and south there are no extensive areas of dry climate due to the configuration of the continent. Even in Central America and Mexico it occurs on both sides of the area of rainy tropical climate: along the south coast of Panama to southern Mexico and on the north side in Yucatan.

It will be noted that in the Western Hemisphere the areas of seasonal rainy climates occur mostly along the west coast and in the interior, and that much of the east coast has the year-round rainy type.

Winds. The tropical savanna type of climate extends far enough north and south of the equatorial zone to include large portions of the trade-wind belts. As already mentioned (page 76), the sun's rays strike the earth at constantly changing angles. The noonday sun is overhead at the Tropic of Capricorn on December 22, at the equator on March 21, at the Tropic of Cancer on June 21, and again at the equator about September 22. Thus, in the course of a year, all places on the globe have at least one high-sun period and one low-sun period; near the equator there are two of each, although the difference between the high- and low-sun positions is not great. At distances of 10 degrees or more from the equator, these periods are well marked, and, of course, insolation is relatively great during the high-sun period and appreciably

less during the low-sun period. As the sun's position moves northward and southward, pressure and wind belts follow suit. Although this shift is not great in the tropical savanna regions, which are located relatively close to the equator, it is sufficient to bring about a slight seasonal rhythm in temperature and a pronounced rhythm in rainfall. During the high-sun period, when the noonday sun stands practically overhead, insolation is at its maximum. The heated air expands and rises, and surface winds are weak and irregular as the trade winds recede poleward. This is the rainy season. During the low-sun period the trade winds reassert themselves. Since they blow toward warmer regions, they give little or no rain except where intercepted by mountains. The low-sun period is therefore the season of drought.

Temperature. Temperatures in tropical savannas average above 65°F., as in the tropical rainy regions, but the seasonal range is somewhat greater. As a rule, the highest temperatures immediately precede the period of maximum rainfall. In the Sudan the hottest months are April and May. In June, when the rains are quite copious, temperatures drop. In Bengal, India, and East Pakistan rains are welcomed because they are accompanied by lower temperatures, and this brings relief from the excessive heat of the preceding weeks.

Rainfall. The rainfall, although abundant, is not excessive. The annual precipitation in most savanna areas is between 30 and 60 inches. Marked seasonal concentration is the most prominent characteristic of the rainfall. Rainfall in these areas is somewhat erratic in annual total and in timing. This underlies a year-to-year variation in crop yields. While the record of Cuyaba, Brazil (Fig. 75), shows a somewhat more irregular march of temperature than do the records of Singapore and French Guiana, the greatest difference lies in the smaller rainfall total and in the existence and duration of a dry "winter" season. The length of the rainy season varies in different sections of the tropical savannas from eight to less than five months. Toward the equator two peaks in rainfall may occur. The dry

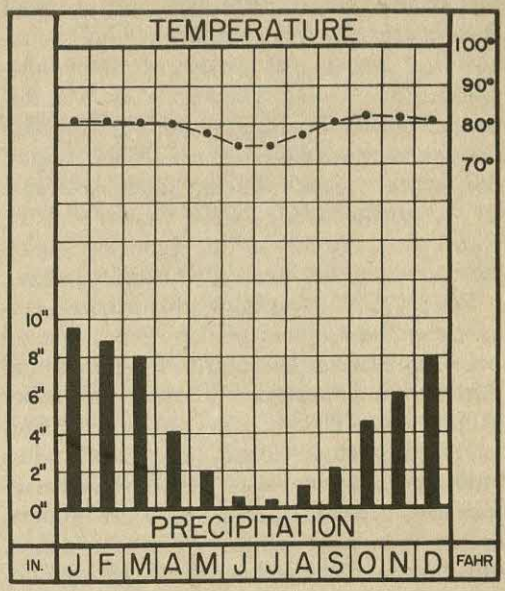


Fig. 75. Savanna climate. Average temperature and precipitation, Cuyaba, south-central Brazil. Altitude 495 feet, total precipitation 55 inches.

season is comparatively brief near the equator, increasing in duration poleward. During the rainy season roads and trails are muddy, in places almost impassable. During the latter part of the dry season the ground and air are parched and dusty, and wooden and leather objects shrink. These pronounced seasonal changes involve greater efforts at adjustment on the part of man than are necessary under a more monotonous regime of rainfall. Storage of food for people and feed for animals is necessary because the dry season is one of low productivity and resulting scarcity.

On the whole, because of the range of temperature and humidity, the regions of the tropical savannas escape the extreme monotony so characteristic of the tropical rainy belt, and the climate is therefore somewhat more conducive to physical activity.

Tropical cyclones. Parts of the savanna areas are visited by tropical cyclones, which originate over the seas, but which sometimes cause great havoc on adjacent land areas. These storms develop at sea

in latitudes 10° to 20° north and south of the equator and thence follow roughly semi-elliptical paths, first westward, then poleward and eastward. They are known in different sections by different names. The term *hurricane* is restricted to the West Indies, the western South Pacific, and Australia. In the northwestern Pacific Ocean and the China Sea, storms of this type are called *typhoons;* in the Indian Ocean, *cyclones.*

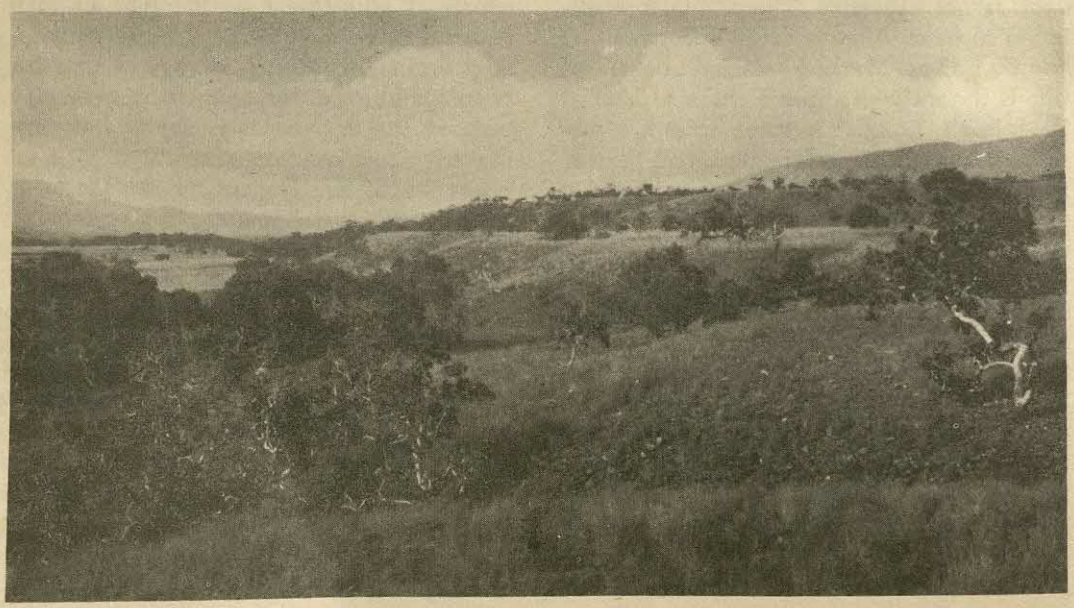
While the atmospheric disturbance created by the tropical cyclones may extend over large areas, the really dangerous and destructive center generally has a diameter of less than 200 miles. Tropical cyclones usually lose their violent energy soon after striking continental land masses, and therefore they generally bring heavy downpours, rather than high winds, to interior points. On the islands and along the coasts the destructive effects upon crops and buildings are often appalling. Wind velocities exceeding 100 miles an hour are frequently experienced; with such winds crops are ruined, trees uprooted, and buildings blown down. This hazard is one of the most serious handicaps to agriculture within the areas subject to these tropical storms. On their way poleward these storms may also affect adjacent areas of subtropical climate, such as southern United States, southern China, and Japan. Some even penetrate as far as areas of intermediate climate, as in Japan and northeastern United States.

Native vegetation. The vegetation in regions of tropical savanna climate ranges from open deciduous forest to stands of grass. The characteristic vegetation pattern is a grassland, with scattered trees, often termed savanna. Along the wetter margins of the savanna climates the trees will stand in clumps separated by areas of tall grass up to twelve feet in height. The trees found in this more humid savanna will be broad leaved and deciduous while along the drier margins of the savanna they tend to be narrow leaved and may begin to show thorns. Along the courses of major streams there may be dense riverine jungle (Fig. 76). This is the type of landscape that prevails over large areas in the southern Sudan and that forms the so-called *campo cerrado* of Brazil. The marked dry season causes general leaf fall and cessation of growth on the part of most broad-leaved trees.

Native fauna. Since tropical savannas have an abundance of grass, a fair supply of water, and a sufficient number of trees

Fig. 76. Short-grass savannas in northern Maracaibo Basin, Venezuela. Scattered deciduous trees on slopelands.

Photo by N.A.B.



and herbs to yield nuts, fruits, and roots, it naturally follows that animal life should also be abundant. Within these regions are the lands of big game in Africa and similar areas of varied wildlife in South and Central America. In Africa this type of climate harbors in its more humid phases the hippopotamus, rhinoceros, and elephant, while the giraffe, wart hog, zebra, the larger antelopes, and other animals that are fleet of foot inhabit the drier sections. In the jungle areas within the savannas are found the tiger and cougar, while in the tall-grass savanna the lion is the king of beasts. In general, the animals of the well-wooded and tall-grass savannas are large and well fed. The numerous varieties include arboreal, aquatic, and ground types, no one of them being strongly predominant. On the whole, they are less arboreal than those of the jungle and rain forest and also less fleet-footed than those of the dry savannas. They include species larger and stronger than their neighbors of either the humid or the semiarid bordering regions.

Soils. The tropical savanna soils are generally reddish to brownish and more deeply colored than those of the tropical forest lands. These soils are subjected to an annual period of desiccation that is lacking in the rainy tropics. They belong to the group of lateritic soils, and as such they are weak in humus and soluble mineral plant foods. However, since they developed in regions where rainfall is not so heavy, the savanna soils may not be as thoroughly leached as those of the rainy tropics. After the land is cleared, the soils are ordinarily quite productive for a few years, but they quickly deteriorate unless manure or fertilizers are applied.

Since the tropical savannas constitute a transition zone from humid to semiarid lands, there is a similar transition in soil characteristics. The soils of the more humid parts of the savanna belt are more thoroughly leached than those of the drier and somewhat cooler areas located farther from the rainy belt. In general the soils of the drier parts of the savanna are more fertile than those of the rainier areas, and they are more easily tilled. Unfortunately, in some of these regions there occur extensive areas where the surface is formed by a dark-red laterite crust, consisting mostly of aluminum and iron hydroxides, which is so hard that footsteps sound metallic when one walks over it. Such land is extremely infertile and not suitable for any agricultural purposes. In other places such a rock-hard layer lies so close to the surface that only a moderate amount of sheet erosion is needed to make the land permanently useless.

As elsewhere, the alluvial lands along streams or along mountain fronts are more fertile because their soils are the result of deposition of the richest detritus washed down from higher, weathered slopes.

Agriculture. The savanna climate is comparatively favorable for agriculture. Population maps reveal extensive areas of moderate to dense population where this climate prevails, in contrast to the few areas of density that exist in the rainy equatorial belt. Its capacity to sustain population is well shown in India and parts of Africa. Although the areas of dense population within this climatic type in southern Asia have more favorable land forms and soils than the areas with corresponding climate in Africa and South America, nevertheless the dense population of the former indicates some interesting possibilities for the latter, especially when pressure of a rapidly increasing world population may provide sufficient incentive to overcome existing natural drawbacks.

Areas of this type of climate have a number of distinct advantages. The dry season gives man more energy than does a continuously humid climate. Clearing the land is easier since much of the land is covered with grass, and the forest stands, if any, are less dense. The young trees, the dead grass, and the slash from clearing bush and trees can easily be burned at the end of the dry season, and the ground can be plowed and planted at the beginning of the wet season. Some types of grasses and grains can be produced advantageously. The rainy season is the growing season. The dry season is harvest time, when the dry air favors complete ripening and hardening of the grain, thus rendering the stored products

less subject to attack by fungi or insects. The grains typical of the drier parts of these regions are the sorghums and millets. In the more humid sections corn, manioc, and bananas are important food crops, and, where irrigation is possible, rice. Sugar cane is a staple crop for local sugar production, and in some places cane sugar takes high rank as an export commodity as well. Cotton is grown for local clothing material, and its cultivation has some commercial possibilities. The inedible character of much of the wild grass and, in Africa, the tsetse fly, have hampered cattle raising. On the whole, in the savanna lands agriculture is better developed than in the rainy tropics, if we compare "farmer type" agriculture, and leave out of consideration the estate type of agriculture.

Since the agricultural products of at least part of the regions with this type of climate are somewhat similar to those of higher latitudes, the savanna areas do not furnish such a large variety of products to American and European markets as do the regions of rainy tropical climate.

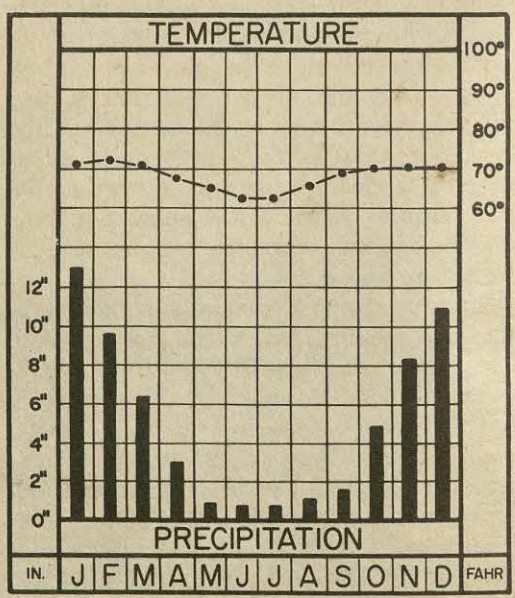
THE TROPICAL HIGHLAND TYPE OF CLIMATE

(Areas marked 3 on World Map of Climatic Regions and Fig. 66.) The tropical highlands differ from the lowlands in having lower average annual temperatures and greater diurnal temperature ranges. Because of the small number of stations with long weather records located within the tropical highlands, the regions as shown on the map at the end of the book have been delineated on the twofold basis of available climatological data and elevation above sea level. The areas of tropical highland type of climate lie mostly at altitudes between 2,000 and 6,000 feet above sea level, but there are some notable exceptions where greater heights are reached, as in Ethiopia and southern Mexico.

The largest area is in Africa, extending from Lake Victoria southward and westward across the headwater districts of the Congo and Zambesi rivers; smaller areas are the Ethiopian highlands and those of Madagascar. Important areas outside of Africa are found in southern Brazil and southern Mexico. We should include the highland areas of Middle America and those associated with the northern parts of the Andes in Colombia and Venezuela, although, unfortunately, they are too small to be shown clearly on the climatic map.

Essential characteristics. Cooler temperature in comparison with the adjacent lowlands is the outstanding feature of the tropical highland type of climate. The average annual temperatures vary from about 65° to 72°F., and the difference between the mean temperatures of the warmest and coldest months of the year is commonly less than ten Fahrenheit degrees. The warmest months are of course associated with the high-sun seasons, the temperatures then averaging from 68° to 78°F. The coldest months occur during the low-sun periods, with averages from about 50° to 65°F. (Fig. 77), representative of the tropical highland climate of Brazil). The difference between day and night temperatures is

Fig. 77. Tropical highland climate. Average temperature and precipitation, Bello Horizonte, north of Rio de Janeiro, Brazil. Altitude 2,571 feet, total precipitation 59 inches.



fairly pronounced. Warm to hot days and clear, cool nights are typical; frosts are rare, but may occur at the highest altitudes.

Rainfall varies greatly in different regions, some regions having only about 20 inches per year, whereas certain others receive up to 80 inches, and more; 40 to 60 inches can be considered a fair average. Periodicity of rainfall is pronounced everywhere. The rainy season occurs during the high-sun period of the year, the dry season during the low-sun period. For areas south of the equator, July is usually the driest month, while the rainy season lasts from October to April, the rainiest month occurring within that period but varying locally. North of the equator opposite conditions prevail.

The trade winds are the dominant winds, and they serve the doubly useful purpose of bringing in moisture and rendering living conditions more pleasant through their steady breezes. On the whole, climatic conditions are quite favorable for human activities, a fact attested by the progressive people who inhabit the highlands of eastern Brazil and southern Mexico.

Native flora. The native vegetation varies greatly from short grass and scrubby bush to dry deciduous forest and even more northern types of forest, in accordance with differences in rainfall and altitude. The rainfall, although fairly heavy, is not sufficiently well distributed to support dense forests except in some favored localities. In general, scattered tree growth, low, thorny scrub, and grass prevail, as, for example, in Africa east and south of Lake Victoria. In Angola and Northern Rhodesia there are open forests with trees 30 or more feet high, yet not dense enough to suppress a grass cover. Some kinds of trees form nearly pure stands, but usually the trunks are crooked and twisted. In other regions there are areas where tree growth is so sparse that the problem of obtaining wood for cooking purposes is a handicap to settlement. The high slopes are usually forested, and the higher parts of the plateaus are favored with a grass cover wherever the tree stand is fairly open or lacking, as on the mountain slope lands above the Valley of Mexico and on the Ethiopian plateaus.

The growth of grass, trees, and shrubs bespeaks the prevalent fertility of the soil of these areas. This growth is due in no small measure to the moderate amount of rainfall and to its seasonal distribution, both factors tending to conserve the soil and its soluble elements.

Soils. Some of the soils of the tropical highlands are similar to those of the rainier sections of the savanna lands; others have characteristics similar to those of the black soils of temperate lands, especially where rainfall is low and a grass vegetation prevails. This dark soil is usually very fertile.

Since the altitudes of these lands are greater, valleys have been deeply eroded in some areas. As a result of the more active erosion in those regions, the soils are younger and more directly related to the bedrock from which they were derived. Fully developed, mature soils are not common in areas of considerable relief, and thus lateritic characteristics are not pronounced.

Where the bedrock consists of basic rocks, such as lavas and intrusives, the resulting soil is reddish in color and relatively fertile. Soils developed from acidic rocks are usually not so productive. It is a noteworthy fact that the most extensive and successful coffee plantations, which supply most of the world's commercial coffee, are located on the reddish soils of tropical highlands as in Brazil.

On the whole, the soils of the tropical highlands resemble those of the savannas but are generally less leached, more readily tilled, and more productive. The application of commercial fertilizers is necessary except where active weathering furnishes the soluble minerals essential for plant growth.

Agriculture and white settlement. The tropical highlands are, on the whole, rather pleasant places in which to live. Temperatures are moderate and characterized by a diurnal rhythm which does much to relieve the monotony of small seasonal changes. Nights are usually cool enough to be invigorating. The winds are just strong enough to give a desirable freshness to the

atmosphere. The rainfall, commonly 30 to 60 inches per year, is sufficient for abundant plant growth, and its seasonal distribution is conducive to well-defined periods of tilling the land and harvesting the crops.

Both grain and cattle production are actively carried on in many areas, and further expansion is probable. The plant and animal diseases characteristic of the tropical lowlands are less evident at these higher elevations. Corn is quite generally grown, sorghums and millets are important in Africa, and the production of wheat and barley is common. The cattle industry on the highlands of Africa and Brazil has met with conspicuous success, although some areas are so remote from markets that thus far only the hides have commercial value. Thus, agriculture resembles to some extent that of the middle latitudes, except that in many areas fruits such as papaya and mango occur, and crops such as coffee and cassava are produced, which are foreign to typical middle latitude areas. Coffee production is so important that the tropical highlands are sometimes spoken of as the world's coffee lands. These areas are the best "white man's lands" in the warm zone, though many of them are handicapped economically by poor transportation.

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9

Major Agricultural Products of the Humid Tropics

For many centuries the humid tropical regions were of commercial importance to the Western world only as sources of luxury articles, among which spices ranked high. When ships were small and traffic on land and sea was slow and hazardous, only products of small bulk, high value, and excellent keeping quality could stand the high cost of transportation and the long delays.

Modern large-scale commercial agriculture in the humid tropics became possible during the past century, when steamships were built for ocean traffic. Now these regions supply many vital raw materials and foodstuffs to the industrialized regions of the temperate zones. In turn, the tropical lands are still largely dependent upon the middle latitudes for the products of modern industry. Tropical countries are at present predominantly agrarian in character. The retarded industrial development in some cases is due to insufficient power and metallic resources, in some to insufficient technical knowledge, while in others it may be attributed to present or recent political dependence upon highly industrialized mother countries. In many parts of the tropics industries are associated primarily with the products of the soil, such as the manufacture of sugar in Java and Cuba. However, in some parts of the humid tropics modern industry is beginning to attain considerable importance. In India the Bombay and Madras districts have become major textile-manufacturing centers, and the iron and steel industry of the Bihar-Bengal region is rapidly growing in importance. Brazil is building up important industries in the state of São Paulo and the Rio de Janeiro region, especially the cotton-textile industry. It can be expected that in the future new industrial regions will develop in the humid tropics, especially where water power or other types of power as well as raw materials are available, and where suitable labor can be found, thus lessening the dependence upon agriculture.

Among the many products of the tropical regions, bananas, cacao, coconuts, and rubber are typical for the areas of rainy tropical climate. Of somewhat less prominence in these regions are spices, medicinal ma-

terials, and cabinet woods. Sugar cane is grown in both the rainy tropics and the regions with a savanna climate, while coffee is produced in areas of tropical highland climate.

Most of the products characteristic of the tropics cannot be grown commercially elsewhere because of their need for high temperatures at all seasons. This is particularly true of bananas, cacao, and coconuts. Some others, like sugar, are not limited to the tropics, but when grown outside the tropical areas of optimum natural conditions, yields are likely to be lower, and therefore costs of production significantly higher.

During the past half century many sections of the humid tropics have become an integral part of the world economy, and in the future, as the population of the earth grows, the tropics are bound to play a role of increasing importance as purveyors of foodstuffs and raw materials for the areas of dense population farther poleward. Even now, events such as war, which impede the exchange of products between the lower and the middle latitudes, may have serious economic consequences. Thus today the agricultural products of the humid tropics are sold largely in markets of the middle latitudes, markets which are far distant. Except for some of the large estates, producing units are relatively small and have little or no control over the price paid for their product. In addition, since many of the tropical products can be produced in any of the widely separated parts of the tropics, new production from a faraway region may suddenly appear on the world market and affect prices in the older producing regions. Price fluctuation is a problem which troubles farm operators throughout the world, but in the tropics, particularly in areas of monoculture, the effects frequently are more serious. Prices of rubber, for example, have ranged since 1930 from an annual average of about $.04 per pound to an annual average of $.60 per pound. In years of low prices business failure is widespread among tropical farm enterprises. This is another factor in favor of the large estate type of enterprise, which usually has sufficient working capital at its disposal to weather periods of depression.

Tropical producers, dependent as they are upon distant markets, face an additional hazard, namely that their product may be displaced through technical change or by the substitution of some synthetic or natural product which can be produced in or closer to the market area. Synthetic coffee exists on a laboratory scale, and research on synthetic tea is underway. Synthetic rubber now accounts for well over half of the rubber used in the United States. For these and other reasons—such as the appearance of devastating diseases—certain types of tropical agricultural production may well be subject to fairly important locational shifts, and producing regions to changes in emphasis from one crop to another during the coming decades.

As has been mentioned in the preceding chapter, much of the agricultural production in tropical areas is still primarily for subsistence purposes. However, during the last half century the estate or plantation type has greatly increased in importance, and in many parts of the tropics native production is also becoming more and more oriented toward export crops and world markets. For example, Western Europe, which has come to rely to an increasing degree upon vegetable fats imported from the tropics, suffered serious fat shortages during both the First and Second World War.

Modern banana production is an excellent example of large-scale estate- or plantation-type tropical agriculture; cacao is a typical crop of native commercial agriculture, while production of tropical vegetable oils and rubber is in the hands of corporations and native growers.

BANANAS

The banana has long been a staple food of the people in the humid tropics. In the United States the sweet banana is so common on the fruit stands that people are led to believe that it is the only kind of banana grown; they are surprised, therefore, to learn that in the tropics there are hundreds of varieties, differing greatly in size, color,



Courtesy United Fruit Co.

Fig. 78. A bunch of bananas nearing maturity. Note that the individual bananas, the "fingers," point upward from the stem.

flavor, and uses. Some bananas are large, others small; some are red, others light tan to deep yellow; some are sweet and edible when ripe, while others are starchy and must be cooked or roasted before they can be eaten. Still others, like *Musa textilis*, the source of Manila hemp, are valuable for the fibers of their leaf stalks.

The large number of varieties makes the banana of paramount importance in the subsistence agriculture of the tropics. The plant furnishes both food and materials for shelter and even for some forms of clothing adapted to tropical conditions (Fig. 78).

Climate and soil conditions. Bananas require year-round warmth and abundant moisture and sunshine. They will endure temperatures as low as 48°F., but the optimum is much higher, about 75° to 85°F. The plant makes enormous demands for water, and therefore is most successfully grown where a rainfall of 60 to 200 inches is well distributed throughout the year. In certain areas where rainfall is deficient during part of the year, but where water supplies are available, production under irrigation is proving quite successful, particularly since in such areas the dreaded Sigitoka fungus disease has not as yet appeared. This is true especially along the west coast of Central America.

Wind is another important factor. While the plant can stand fairly strong winds during its growing period, a blow of 20 miles an hour may prove disastrous when the fruit is maturing. Finally, bananas require fertile, friable, well-aerated soils. From these requirements it is clear that the banana, though produced throughout the tropics, generally finds optimum conditions for large-scale commercial production in the areas with a rainy tropical climate.

Principal commercial species. From a commercial standpoint, the most important species of banana is *Musa sapientum*. The species presumably was native in the tropical lands of the Far East, but was early brought to the Western Hemisphere and is now found growing in the humid lowlands throughout the rainy tropics. The principal variety is known as *Gros Michel*, the fruit of which is large, well flavored, and capable of standing shipment—qualities which give it commercial leadership. A less popular variety is the red banana, known also as *Baracoa* and *Red Jamaica*. The fruit is shorter and stubbier than that of the *Gros Michel*, and the bunches are smaller.

Another species of the same family is the *Musa paradisiaca*, Fruit of Paradise, more commonly called the plantain or platano. It is in common use in the tropics as a starch food, like our potato, but does not enter into world trade.

Localization and international trade. Major commercial production centers in the lands around the Caribbean, near the greatest consumer of bananas—the United States.

This country generally imports over 50 million bunches of bananas per year, a condition which has prevailed since the early 1920's (Fig. 79). It is interesting to note that, on the whole, imports apparently have not kept pace with the increase in population of the United States. A serious decline in imports took place during the Great De-

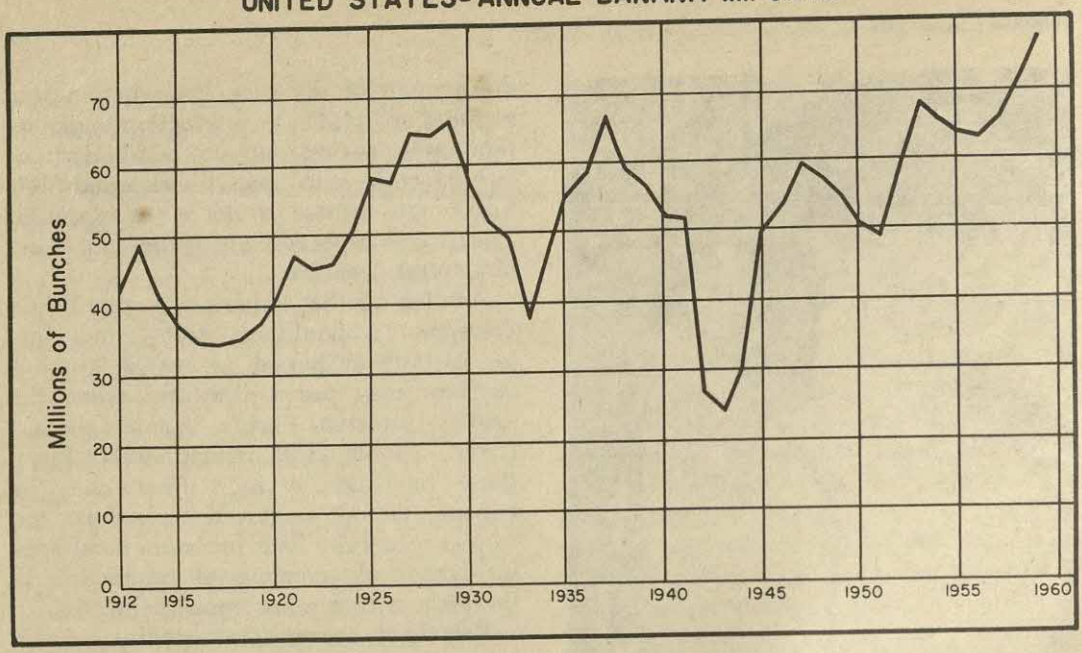


Figure 79.

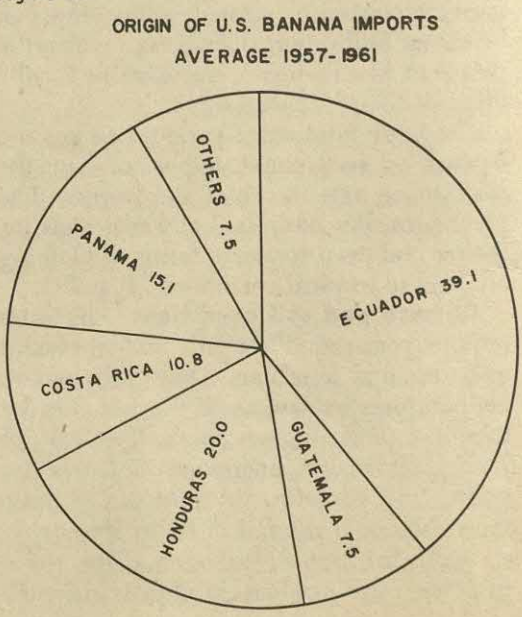
pression of the 1930's, and interruptions in imports were caused by the First and Second World Wars.

Bananas are produced in and exported from many parts of the Caribbean area, but major producers are Costa Rica, Honduras, Panama, Colombia, Guatemala, and Mexico. In neighboring South America, Ecuador exports considerable quantities of bananas to the United States (Fig. 80). Other important exporters are Brazil and the Canary Islands. There are smaller exports from several West African countries. Bananas are produced in considerable quantities in southern Asia, from India to the Philippines, but only Taiwan exports quantities of any commercial significance.

Because of the perishable nature of the banana, large foreign shipments became possible only after modern, fast methods of transportation were developed, with specially built steamships, loading and unloading equipment, warehouses, and railroad cars.

Local production by unsupervised natives failed to provide a supply of fruit dependable both as to quantity and quality, and it soon became evident to leaders in the commercial banana industry that success could be attained only through coordination of production, harvesting, transportation, and marketing processes. At the turn of the century great corporations were organized on that basis, and since then the industry has become a huge, integrated business involving complete coordination of all processes from the planting of the bit in the tropical lowland to the delivery of the ripened fruit

Figure 80.



to the retailers in American and European cities.

Commercial production. The long growing period before harvest and, in the meantime, the expenses of cultivation add to the large-scale capitalistic character of the commercial banana industry. In most regions profitable returns are not expected within two or three years after planting.

The banana is propagated from rhizomes and suckers. Plantations are first set with pieces of rhizome or rootstock, called *bits*, selected from vigorous, healthy plants. During the growth of the plants, *cleaning* must be done three to five times a year. This consists of cutting away with a machete the ever-luxuriant weeds and undergrowth.

A period of 11 to 14 months is necessary for the banana tree to attain maturity and develop its blossom, at which time it reaches a height of 16 to 30 feet, depending on soil and weather conditions. Three to four more months are necessary for the development of the fruit to the point where it is ready for cutting. It is thus from 14 to 18 months after planting before the first crop is ready, and that crop is usually of little value because the root systems have not developed sufficiently to produce the full-sized bunches of large, plump fruit demanded by the trade (Fig. 78). While the mother plant is maturing its bunch of fruit, young sprouts known as *suckers* make their appearance. Soon after the bunch of bananas has been gathered, the stem of the plant is cut down, for each tree bears but one bunch or stem of fruit. The suckers are then removed from the inner side of the basal stem, only a limited number being allowed to develop along the outer edge. These suckers bear the first profitable crop. After that production is virtually continuous during the life of the plantation, a period varying in different regions from 5 to 15 years, or even longer. As the plantation ages, the original single plant becomes succeeded by a sort of circular hill or *mat*.

Harvesting and marketing. The harvesting and marketing processes, as operated by the major fruit companies, are excellent examples of coordination and modern techniques. As the incoming ship approaches the port, radio instructions are sent from company headquarters to the local managers notifying them as to the number of stems desired, the exact hours for loading, and the destination of the cargo. The local managers then instruct the superintendents of the banana farms by telephone as to the number of stems each is to supply and for what market the cargo is destined. The probable number of days that will elapse from the day of cutting until the fruit reaches consumption centers is estimated; cutters are advised accordingly, and orders are issued to time the work so that the fruit is delivered and the cars are loaded at the railroad sidings but an hour or two before the engine comes along to make up its train for the trip to the port. The railroad trip may be 10 miles or it may be 60, but the work is so integrated that the loading of the cargo of 40,000 to 80,000 stems is accomplished in 8 to 12 hours without congestion or confusion. The clocklike precision with which these processes of harvesting and transportation are carried on is necessitated by the climatic conditions and the perishable nature of the fruit.

CACAO

Cacao is one of the crops most typical of the areas of rainy tropical climate. The cacao tree (*Theobroma cacao, Theobroma* = food of the gods) is a native of the American tropics, and its cultivation has spread to tropical parts of other continents. The tree is restricted to tropical lowland areas, for it requires an average temperature of at least 75°F. and a minimum temperature that does not fall below 60°F. Humidity ranging between 80 and 90, and rainfall of 50 inches or more per year are essential. Commercial success is not possible where there is a marked dry season. In many regions it has been found advantageous to provide shade by interplanting other, taller trees, referred to as *madre de cacao* (or cacao mother) in Latin America, in order to prevent excessive evaporation.

The damp, warm climate required for commercial production of cacao unfortunately favors plant diseases, and cacao has

probably suffered from these more than any other commercial crop of the tropics.

Production. The cacao tree blooms continuously and always carries some ripe fruit. Usually, however, there are one or two principal harvests during the year. The fruit is a pod containing a number of seeds, the cacao beans. The beans are shelled from the pod, subjected to a fermentation process, and dried; they are then ready for shipment. The processes of preparing cacao for market are therefore essentially simple and do not require costly equipment. Once the beans are prepared, they keep well, and no special transportation facilities are needed. Thus cacao does not need to be grown on large plantations, but can be produced in satisfactory qualities by native farmers (Fig. 81).

In preparation for consumption the beans are cleaned, dried, and roasted. Chocolate is produced by adding some sugar to the finely ground beans. Cocoa is made by removing most of the vegetable fat, the so-called cocoa butter, which is in great demand for the preparation of cosmetics. The rapid increase in consumption of cacao during recent decades is due to the production of cheaper sugar and a general rise in the standards of living.

Distribution. Most of the cacao that enters world trade is derived from two types of cacao, the *Criollo* and the *Forastero*. The *Criollo* type, planted principally in America, furnishes a cacao of superior grade, in great demand for blending purposes, but the tree gives rather low yields and shows little resistance against disease. The bulk of the world's cacao, including the African crop, is produced by the *Forastero* type. The trees are hardy and yield well, but their product has an aroma deemed inferior to that of the *Criollo*.

Tropical South America, especially Ecuador, and the West Indies were for centuries the world's main source of cacao. In the latter part of the nineteenth century a new area of production began to develop in

Fig. 81. Picking cacao pods on a plantation in Ecuador. Note pods attached to trunks of trees. Women in foreground are shelling the cacao beans from the pods.



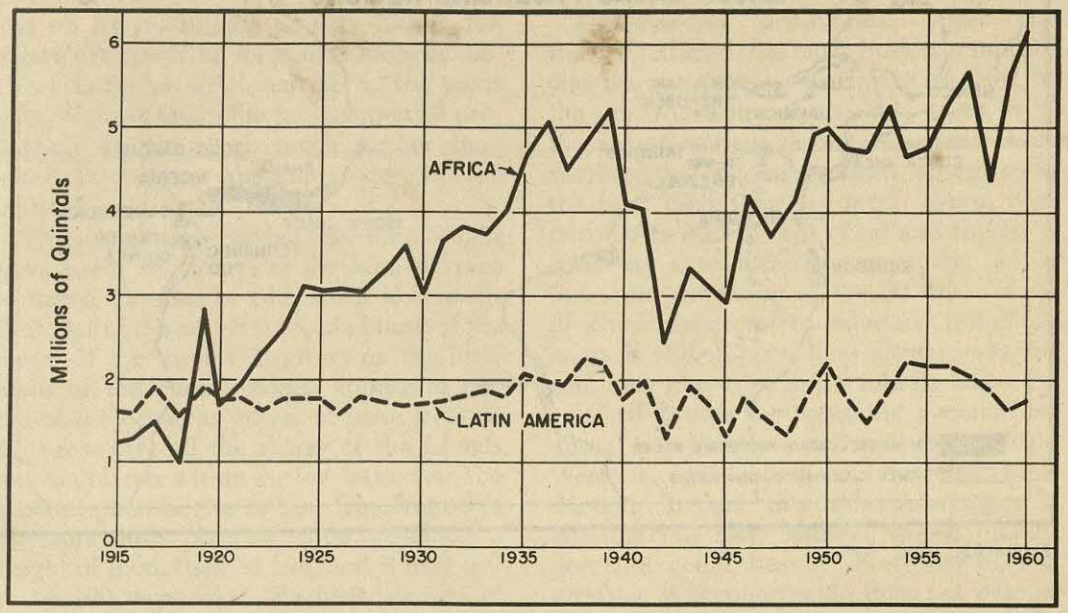


Figure 82.

Africa, first on the islands in the Gulf of Guinea and later on the Guinea coast itself. By 1920 this area had definitely outstripped the old centers of production in the Western Hemisphere (Fig. 82).

Almost one third of the world's cacao crop comes from Ghana, in Africa. Other portions of the tropical rain-forest belt that skirts the Gulf of Guinea also produce cacao. Along the coast of Nigeria the cacao industry is steadily increasing in importance, and sufficient land is available for considerable expansion. The French established an important cacao industry in the Ivory Coast, and normally the bulk of the output is shipped to France. Producers of lesser importance are Cameroon and Spanish Guinea. In Africa the cacao plantations are mostly in the hands of the natives, with only a minor percentage of European estates (Fig. 83).

In America the principal centers of production are much more scattered. The newest, and at the same time the most important, producer is the state of Baiá, which makes Brazil second only to Ghana in world output. The cacao is grown on the river flats and lower hills of the coastal strip, where temperatures are high and where the southeast trade winds provide abundant precipitation. Brazilian cacao is comparable in quality with that from Ghana and brings only slightly higher prices. Another important producer of ordinary cacao is the Dominican Republic.

Superior grades of cacao are exported by Ecuador and, in smaller quantities, by Venezuela and Trinidad. In Venezuela the majority of the cacao plantations are located in the narrow coastal strip east of Puerto Cabello and in the region around the southern end of Lake Maracaibo. In Ecuador the industry centers in the valleys north of Guayaquil. Ecuador was once the world's principal cacao producer, but with the expansion of the industry in other areas the country lost its predominance, and the advent in 1922 of witches'-broom, one of the most dreaded cacao diseases, for a time threatened to annihilate the industry. Other producers of some importance in America are Costa Rica and Mexico.

International trade. Europe and North America account for most of the world's cacao imports, the United States alone taking about one third of the total. More than half of the imports of cacao beans come from Africa; most of the remainder origi-

STATE Gov't. of West Bengal

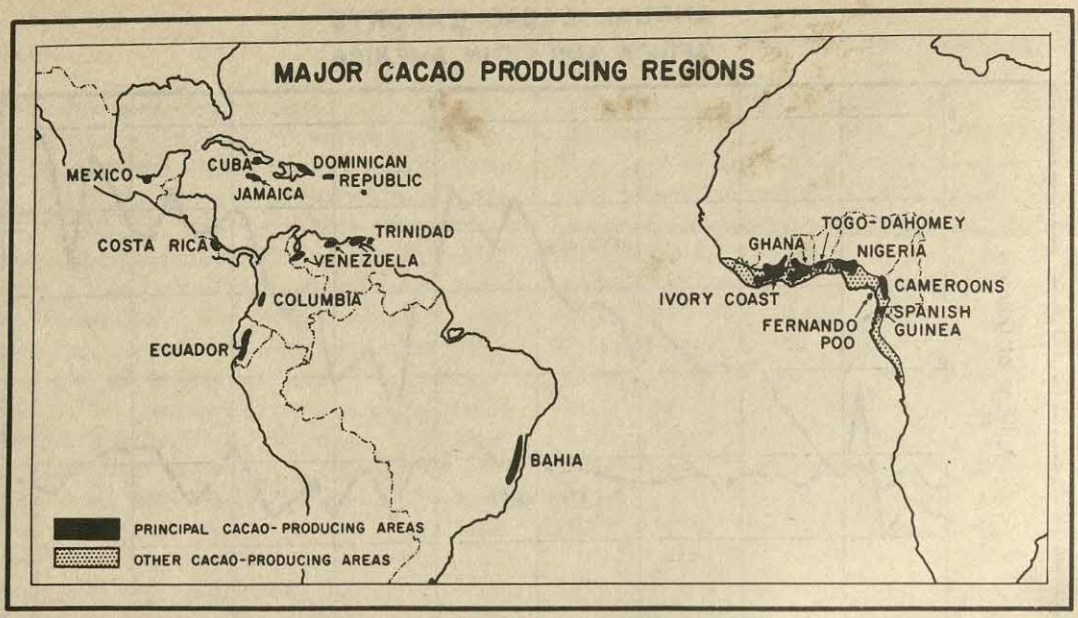


Figure 83.

nate in Latin America, especially Brazil. The chief competitors of the United States in the purchasing market are the United Kingdom, West Germany, the Netherlands, France, Belgium, Italy, and Switzerland. The Netherlands have a highly developed cacao industry and export considerable quantities of cocoa, cocoa butter, and chocolate. Switzerland is known as an exporter of chocolate and chocolate products.

TROPICAL VEGETABLE OILS

Fats are an indispensable part of the human diet, and many kinds of fats and oils are necessary for a multitude of modern industrial processes. In some parts of the world climatic conditions are such that it is either impossible or impractical to produce animal fats. In the tropical savanna climates, for example, it is not possible to make hamburger from local beef because the meat has so little fat. In regions of dense population the production of animal fats is relatively expensive, and with the continued increase in the population of the world, the shortage of animal fats is becoming ever greater. In world trade the importance of vegetable fats is already far greater than that of animal fats, and the world production of vegetable fats is increasing at a rapid rate. The densely populated countries of Europe have been looking to the tropics as one important source area for vegetable fats. Coconut palms, oil palms, sesame, and peanuts are the principal oil crops which are produced successfully in the tropics, and there are a number of other crops that hold promise for the future.

The coconut palm. The coconut palm is one of the plants indispensable to primitive native economy in many parts of the warm humid regions. Its products are so diversified that a small grove suffices to assure tropical man of all he needs for survival: food and drink, implements, shelter, and a little clothing. During recent decades, however, the importance of the coconut palm has extended far beyond the tropical lands; its fruit has become one of the principal sources of vegetable oil for the inhabitants of the industrialized temperate regions and for the manufacture of soap and margarine.

The coconut palm (*Cocos nucifera*) requires much sunshine and continuous warmth. (See Fig. 84.) Although it can stand brief periods of temperature as low as 60°F., it does not thrive where average annual temperatures are below 75°F. High humidity and high annual precipitation, preferably over 80 inches per year, are essential; periods of drought have an unfavorable influence both on the palm itself

and on its production of nuts. While the outermost limits of its distribution lie between latitudes 26°N. and 22°S., the areas with climates favorable for commercial production do not reach much farther than about 20 degrees on either side of the equator.

There is a native saying that the coconut palm needs the sound of the human voice to thrive. One might add that it also needs the voice of the sea: it is an inhabitant of the coasts of the tropics. It grows on the little atolls of the Pacific, which appear to rise out of the ocean as groves of palm trees; it fringes nearly all the shores of the islands and mainlands within the low latitudes. The coconut palm begins to bear fruit from 8 to 10 years after planting, often reaching a height of more than 80 feet, and it may live to be 100 years old. The fruit consists of an outer fibrous cover enclosing a hard, woody nut lined with "meat." This meat is valuable commercially because of its high content of vegetable oil. Not only is this oil an excellent soap stock, but its chemical composition is so closely akin to that of butter that, after being refined, it can be made into high-quality oleomargarine.

Commercial production. After the fruit is gathered, the outer husk is removed, and the nut split open. Then it is dried in the sun over a fire or, in a few cases, with the aid of modern drying apparatus. As a result of this process the meat loosens from the hard shell. The dry meat, *copra*, contains 50 to 60 per cent of oil and thus is a relatively concentrated commodity. Sometimes the extraction of the oil takes place in or near the areas of production, but much copra is still shipped long distances to the consumer countries in the middle latitudes.

In all producing areas the coconut industry is primarily a native industry; little Western capital has been invested in production. In part, this is because copra is essentially a raw material whose quality does not count heavily. Furthermore, the growing of coconut palms does not require a knowledge of specialized agriculture. Its growth is thus an ideal economic activity for the natives, who can sell their copra when prices are favorable and can wholly or partially withdraw from the market when prices are low.

The centers of commercial coconut production are the Philippines, Indonesia, the



Fig. 84. A coconut grove in Indonesia. The coconuts are transported by oxcart to the village for the preparation of copra.

Courtesy Indonesian Information Office

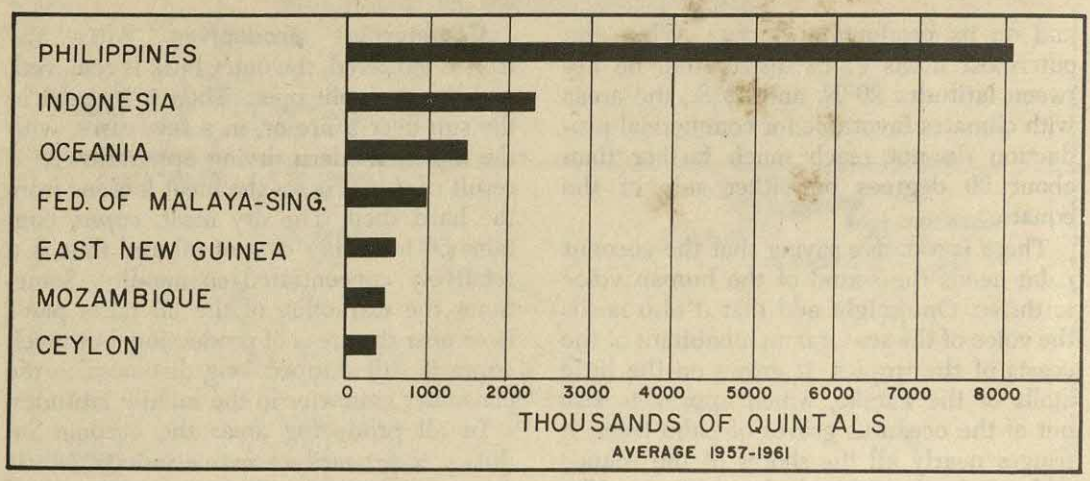


Figure 85.

islands of the western Pacific (especially New Guinea and the Fiji and Solomon islands), Malaya, East New Guinea, Mozambique, and Ceylon (Fig. 85). In the Philippines the industry is concentrated in the eastern and southeastern sections of the islands, where rainfall is high and where there is no prolonged dry season. The Philippine industry is strongly dependent upon the American market. Large quantities of copra and coconut oil are shipped to the Pacific ports of the United States, especially to Berkeley, California, where an important oil-crushing industry exists. Smaller quantities are sent directly to Atlantic ports. An oil-crushing industry has developed in Manila, the only center in any of the producing areas where the oil is extracted on a large-scale basis. Because of the favorable economic and political connections, the oil normally is exported directly to the United States.

In Indonesia the commercial coconut industry is most important in the sparsely populated outer islands, especially in Celebes, western Borneo, Sumatra, and the Moluccas. The exports are sent mostly to European markets. There was a drastic decrease in copra production and export in Indonesia during the 1950's.

North America and Western Europe are the principal consumers of copra and coconut oil. In the United States most of the oil is used for various technical purposes, such as the manufacture of soap. In Europe, on the other hand, much of it goes into the manufacture of oleomargarine. Dried, shredded coconut meat is used in confections and pastries.

The only other coconut product of commercial value is the fiber of the outer husk, known as *coir*. It is used in the Orient for the manufacture of rope and other cordage, and it serves in Europe for the manufacture of coarse but strong matting. It is used in small quantities in the United States for the manufacture of door mats.

Whole coconuts are not of great importance in international trade because they are too bulky and of too low value to stand long distance transportation. In the United States the whole nuts come mainly from the nearby Caribbean lands.

Oil palm. The African oil palm (*Elaeis guineensis*) is a competitor of the coconut in the markets for vegetable oils in the middle latitudes. Like the coconut palm, the tree requires a rainy tropical climate. It needs high humidity and a rainfall of over 80 inches, and it cannot survive a prolonged dry season (Fig. 86).

In Africa the trees are found scattered through the humid forests of the Guinea coast and the Congo basin, and from time immemorial they have furnished the Negro with a food and an unguent. In clearing the jungle the natives have generally left the oil palms standing. Protected by the Negro



Courtesy Embassy of Federation of Malaya

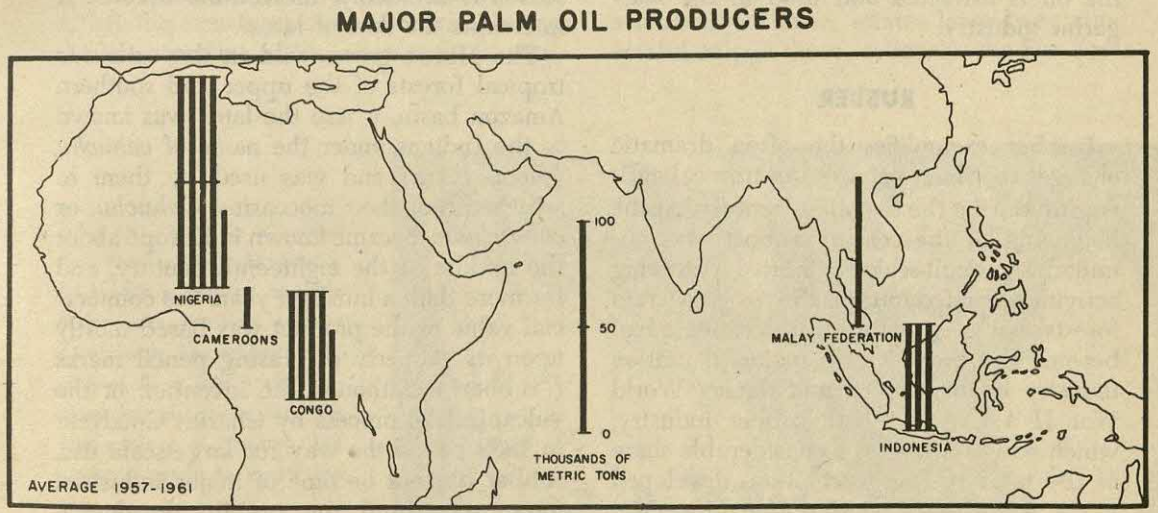
Fig. 86. View in an oil palm estate in the Johore section of Malaya.

farmer, these palms have multiplied until in many regions they have developed into solid groves. Oil-palm stands are especially extensive in the moist coastal lands of Nigeria and Dahomey, and a belt in which they are common stretches westward along the entire Guinea coast almost as far as Senegal. Toward the south, oil palms occur in the Cameroons, Gabon, the Congo region, and coastal Angola.

The fruit of the oil palm is small, from one to two inches in diameter, yellowish white, and grows in bunches which may contain as many as 1,000 to 1,500 each. It consists of a soft yellow pericarp and a hard kernel, of which the former contains the palm oil proper, the latter, the palm kernel oil.

The oil is pressed from the pericarp with the aid of primitive native equipment, often simply by means of treading. While much of the oil is used locally, a large supply is available for export. The hard kernels keep well, contain about 45 per cent of oil, and are shipped mostly to northern countries. Principal shippers of oil are Nigeria, the Congo, Indonesia, and Malaya. Major exporters of palm kernels are Nigeria, the Congo, Dahomey, and Sierra Leone (Figs. 87 and 88).

Figure 87.



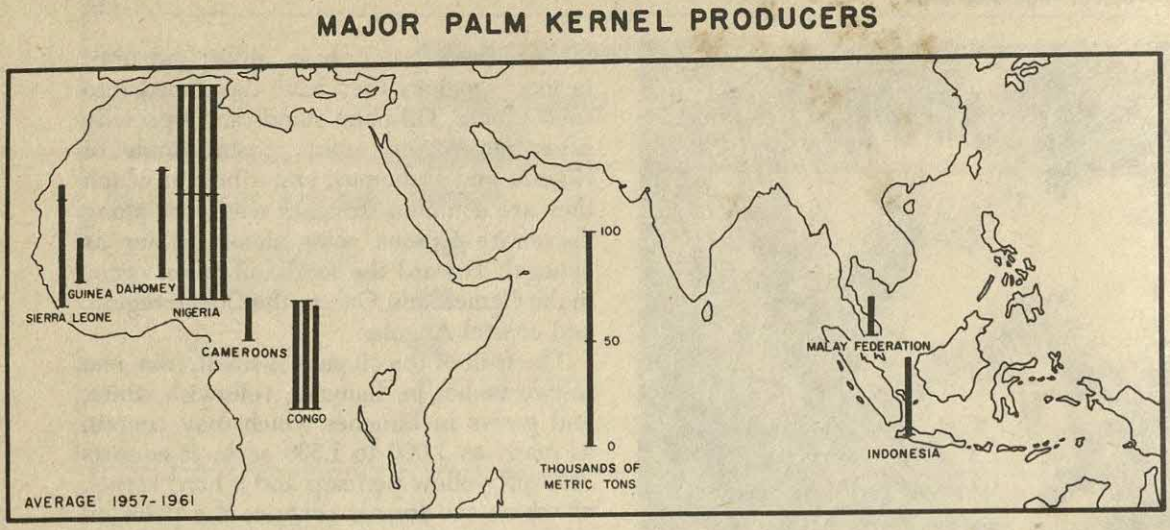


Figure 88.

Several decades ago extensive plantations of oil palms were established under Western management in Indonesia and Malaya. This plantation industry proved to be able to compete with the African industry. The oil produced is carefully prepared, has a low content of free, fatty acids, and is therefore in great demand (Fig. 86).

The centers of consumption of palm oil are Western Europe and the United States. The United States imports come principally from Indonesia, though Africa, especially the Congo, furnishes some. Most of the palm kernels are shipped to Europe, where the oil is extracted and used in the margarine industry.

RUBBER

Rubber exemplifies the often dramatic changes that have occurred in tropical agriculture during the twentieth century. At the beginning of the century rubber was obtained by small-scale, primitive gathering activities carried on in the tropical rain forests; however, within two decades it had become the product of a major plantation industry in the tropics, and during World War II a large synthetic-rubber industry, which now contributes a considerable share of the total rubber production, developed in the countries of consumption (Fig. 89).

Rubberlike substances are known to exist in many plants of the intermediate as well as of the tropical regions. Thus far, however, the largest and most satisfactory rubber-producing plants have been found in warm regions where rainfall and humidity are high throughout the year. Among the numerous actual or potential producers, the Hevea tree (*Hevea brasiliensis*) has attained preeminence because of its high yields and the excellent quality of its rubber. The bark of this tree yields a ready flow of latex, a milky juice not unlike that of the American milkweed. It requires a rainy tropical climate; a pronounced dry season is decidedly unfavorable because it interrupts the flow of latex.

The Hevea grows wild in the extensive tropical forests of the upper and southern Amazon basin, where the latex was known to the Indians under the name of *cahuchu* (wood tears) and was used by them to weatherproof their moccasins. *Cahuchu*, or *caoutchouc*, became known in Europe about the middle of the eighteenth century, and for more than a hundred years the commercial value of the product was based mostly upon its property of erasing pencil marks ("rubber"). Although the invention of the vulcanization process by Charles Goodyear in 1839 paved the way for large-scale use, rubber did not become of major industrial importance until the rapidly developing bicycle and automobile industries created

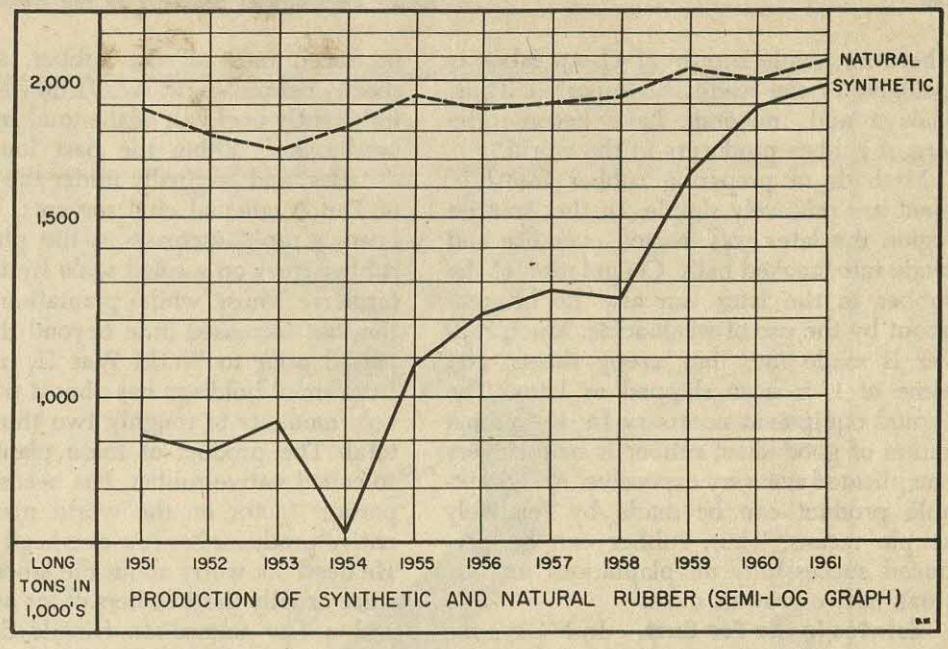


Figure 89.

an enormous demand for it. With a large part of the civilized world riding on pneumatic tires, rubber has become one of the raw materials indispensable to our present industrial age.

Change from gathering to estate agriculture. The inhospitable tropical environment and the scattered distribution of the Hevea trees through the forest proved to be great handicaps in the exploitation of the wild rubber resources of the Amazon basin. It soon became evident that the supply of wild rubber was not sufficient to satisfy the ever-increasing demands. During the latter portion of the nineteenth century, efforts were made to introduce the Hevea in other parts of the world and to cultivate it on estates. These attempts were highly successful, and at present most of the world production of natural rubber is derived from the estates and small native plantings. The wild rubber output of Brazil has fallen to a negligible percentage, although World War II stimulated a temporary increase.

Tapping the trees is laborious and requires considerable skill (Fig. 90). In order to have each tree tapped every other day, an abundant supply of low-priced labor is a necessity. Hence, estates have been successful only in those sections of the Far East



Fig. 90. Tapping a rubber tree. Preparatory to tapping, a fresh oblique incision is made in the bark. Previous incisions show clearly. The rubber "milk" or latex flows into a cup fastened temporarily to the tree with a piece of bamboo. The worker is ready to empty the cup.

Courtesy Indonesian Information Office

where an ample supply of cheap labor is available or can readily be imported. Thus, Malaya and Indonesia have become the largest rubber producers in the world.

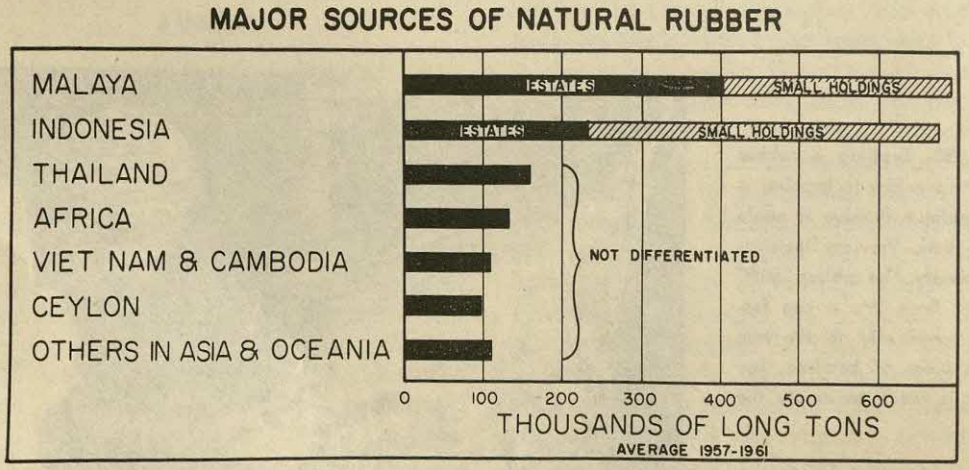
Methods of preparing rubber for shipment are relatively simple. In the Amazon region the latex was treated over fire and made into smoked balls. Coagulation of the rubber in the latex can also be brought about by the use of weak acids. Much rubber is made into thin, crepy sheets, and some of it is even shipped as latex. The capital equipment necessary for the preparation of good sheet rubber is neither very complicated nor very expensive. An acceptable product can be made by relatively simple means. Thus, rubber can be produced successfully on plantations and by small native growers alike.

Estates in the Far East. In Malaya the estates are mostly on the low coastal plains; a few are in the hilly belt farther inland. Climatic conditions are ideal, but much of the labor is imported, mostly Tamils from India and Chinese from the southern part of China.

In Indonesia rubber is produced in all the western islands. Modern rubber estates, initiated early in the present century by Dutch, English, American, and French capital and now partly nationalized by the Indonesian government, are found especially in Sumatra and Java. In the beginning the estates produced most of the rubber, and even shortly before World War II they accounted for slightly over half of the total Indonesian production. Within the past four to five decades, and originally under the direction of Dutch colonial civil servants, there has been a rapid increase in the planting of rubber trees on a small scale by individual farmers. Thus, while plantation production has increased little beyond that of the period prior to World War II, production from small holdings has almost tripled and now amounts to roughly two thirds of the total. The product of these plantings, the so-called native rubber, has become an important factor on the world market. The native producer has few overhead expenses. He need not worry about the labor problem since usually the members of his own family and a few immediate friends do all the work; he does not have above him a board of directors and shareholders clamoring for dividends. Thus, he can tap his trees whenever prices are favorable, and when the market goes down he can discontinue tapping without incurring serious losses.

Thus native competition has raised a serious question for the plantation rubber industry. After all, rubber is only a raw material of industry, and it does not need the extreme care given to it on the estates. The Hevea is a hardy tree and lends itself well to rather inefficient methods of cultivation.

Figure 91.



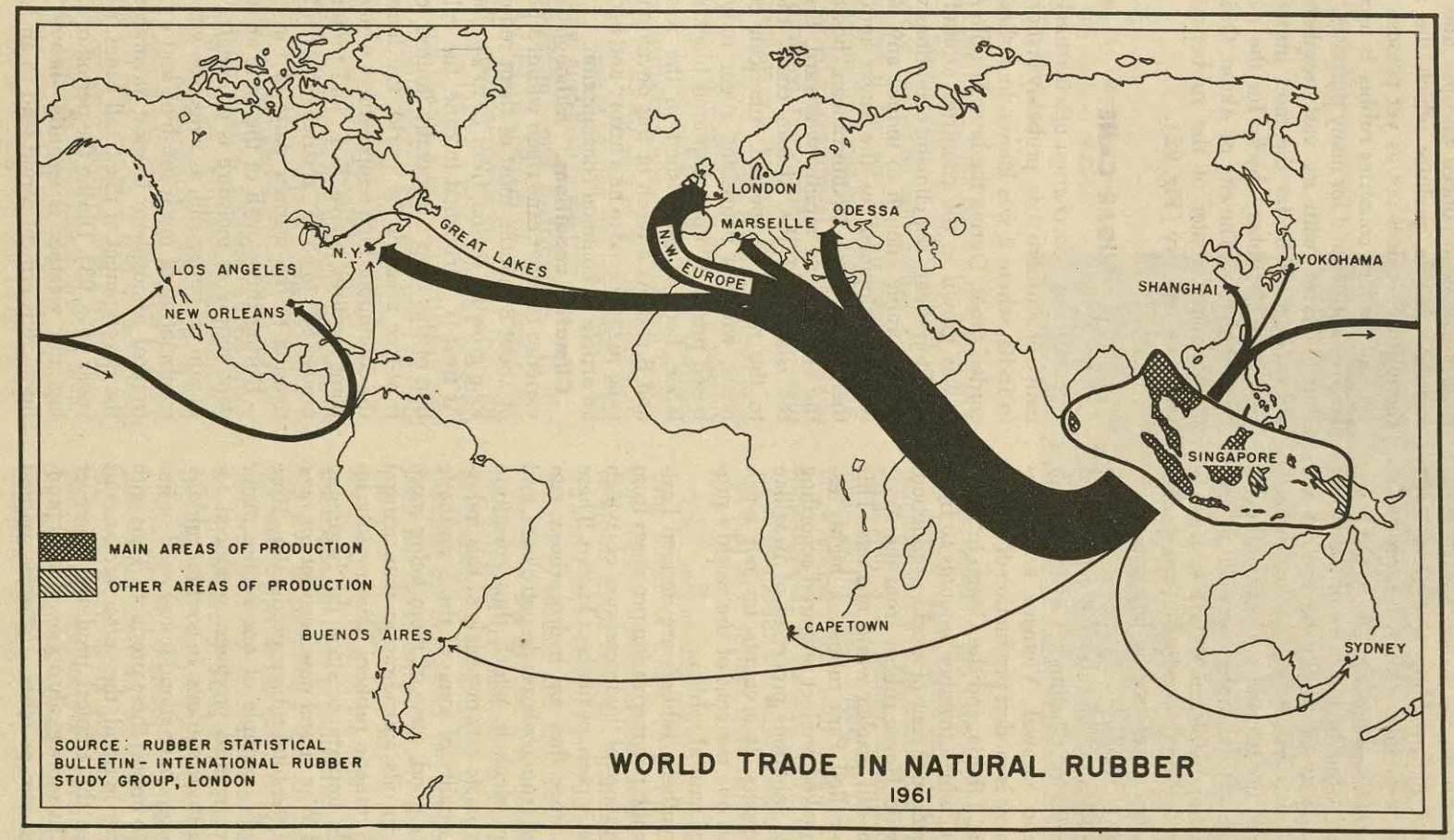

LONDON
MARSEILLE
ODESSA
N.W. EUROPE
GREAT LAKES
N.Y.
LOS ANGELES
NEW ORLEANS
YOKOHAMA
SHANGHAI
SINGAPORE
CAPETOWN
BUENOS AIRES
SYDNEY
MAIN AREAS OF PRODUCTION
OTHER AREAS OF PRODUCTION
SOURCE: RUBBER STATISTICAL BULLETIN - INTENATIONAL RUBBER STUDY GROUP, LONDON
WORLD TRADE IN NATURAL RUBBER
1961

Figure 92.

On the other hand, the plantations can carefully select high-yielding trees and graft parts of these on low yielders. It is probable, however, that in the rubber, as in the coconut industry, the largest share of the world production may eventually be contributed by native growers, provided that synthetic rubber does not become so cheap and good as to make natural-rubber production economically impossible. In Malaya estate production still exceeds production from small holdings, but here also the latter is slowly increasing (Fig. 91).

Small quantities of rubber are produced in southwestern Thailand, Ceylon, North Borneo and Sarawak, Vietnam, and Cambodia. There is modest production of rubber in Nigeria, Liberia, and the Congo in western Africa, which together amounts to from five to seven per cent of world production.

Some wild Hevea rubber from the Amazon basin still reaches world markets. This is the so-called Pará rubber, a highly esteemed smoked product prepared according to the old laborious processes of Brazilian native tappers. It accounts for not much more than one per cent of the world's production of natural rubber.

Most synthetic rubbers are derived basically through polymerization processes from a small group of hydrocarbons of which butadiene is perhaps the best known. These "dienes," since they are hydrocarbons, can be derived from coals, crude petroleum, and even from alcohols, which thus constitute the major basic raw materials of this industry. The quality of some of these synthetic rubbers is good, some of them being more resistant to oils and abrasion than natural rubber. Synthetic rubbers have rapidly increased in importance since the beginning of World War II and now account for over a third of the total rubber production. Here is a specific example of one of the major threats to tropical products, produced for middle-latitude markets. In wartime middle-latitude users have found it awkward or impossible to import these products. Thus with fear of war in mind, they often are anxious to replace the tropical products wherever possible, by more easily obtained local products, synthetic or other. However, natural rubber can be produced cheaply and has certain valuable qualities which the synthetic product does not as yet possess.

In all modern countries rubber is used in large quantities and for many purposes. The United States, with its vast numbers of automobiles, is by far the most important consumer of rubber, chiefly for the manufacture of tires. The city of Akron, Ohio, is the principal center of the rubber-manufacturing industry (Fig. 92).

SUGAR CANE

Sugar cane (*Saccharum officinarum*) is a native of southern Asia, probably first grown in India, where it was known in earliest recorded times. During the later Middle Ages it was grown in the countries around the Mediterranean, but climatic conditions were not favorable enough to induce any large-scale development of the sugar industry there. From the Mediterranean, however, the crop spread rapidly westward, first to the islands off the African coast, thence to the newly discovered American continents, where a flourishing sugar industry, based primarily upon imported black slave labor, became established in the Antilles and Brazil. As a result of this development, cane sugar ceased to be a luxury and became an article of common consumption.

Climatic conditions. Although some varieties of sugar cane ripen within a period of about 8 months, most of them require a long growing season, from 12 to 24 months. As frost is detrimental to cane, the cultivation of this crop is generally limited to the frost-free areas of the world. Furthermore, the continuous high temperatures which the plant requires, above 70°F. and preferably around 80° to 85° F., restrict successful cultivation to the warmer parts of the earth.

During the growth of the cane an abundant supply of moisture is essential, either as rain or, better still, as irrigation water. A combination of much sunshine and a damp tropical atmosphere is most favorable for the development of thick, tall canes, rich in sugar (Fig. 93). During the period of ripening, dry weather is essential—heavy rains during this critical period lead to an appre-



Fig. 93. Harvesting sugar cane with machetes in Cuba.

Photo by A. Eagle

ciable dilution of the juice, and hence to a lower percentage of sugar. Sugar cane, therefore, cannot be cultivated to economic advantage in the very humid tropics, as for example in the Amazon or the Congo basins. The world's commercial sugar plantations are confined principally to tropical lands where there is a short dry season.

In both hemispheres, but especially in the Northern Hemisphere, sugar cane reaches well into the subtropics, as in northern India, southern China, and southern United States. There the shorter growing season results in cane of smaller size and lower sugar yield per acre than in the tropics.

Production and distribution. In the commercial production of cane sugar, one of the principal problems arises from the fact that cane is a raw material of great bulk, and during a brief harvesting season huge quantities must be transported quickly to a central crushing plant, where the raw sugar is extracted. Commercial production of sugar cane therefore tends to be confined to lowland areas where transportation is easy. Most plantations are large so that efficient transportation systems can be established. Such systems usually consist of a network of narrow-gauge tracks over which small engines can draw long trains of heavily loaded cars. In many regions additional cane is grown by natives and sold to neighboring "centrals," the plants that manufacture raw sugar, the basic product for the manufacture of refined sugar (Fig. 94).

The modern processes of sugar refining are rather complicated and require costly machinery as well as a high degree of technical skill. The commercial manufacture of sugar is therefore mostly in the hands of large corporations with ample capital at their disposal. In contrast to the rubber and copra industries, the sugar industry thus far has had little to fear from native competition.

The outstanding surplus producer of cane sugar is Cuba. (See Fig. 95.) Except for the occasional occurrence of severe droughts, Cuba enjoys a climate that is ideal for sugar cane. Only 12 to 15 months are required to mature the crop, and once the cane is in the ground the rootstocks continue to send out new shoots for a number of years, thus eliminating the cost of replanting the fields after the harvest. Fertile land has been comparatively abundant in the past. Sugar cane has occupied only about 13 per cent of the total land area of the island, and has produced harvests yielding five to six million tons of sugar. It is estimated that in the early 1960's about 25 per cent of the land area was under cultivation for all crops. This, if need be, could be increased to somewhere around 65 per cent (much of the potentially cultivable land is now being used for pasture). Thus there still are large areas available for the expansion of sugar acreage, even though an increasing population will also require increases in food-crop acreages. Since land has



Courtesy Embassy of the Dominican Republic

Fig. 94. Unloading sugar cane at the mill from a truck that has hauled it in from the fields. Rio Haina sugar mill in the Dominican Republic.

been inexpensive, at least in comparison with sugar land in, for example, Java (which has a much denser population than Cuba), cane cultivation has been on the extensive side, with rather low yields per acre. Sugar yields per acre undoubtedly can be increased by somewhat more intensive methods of cultivation, improved varieties of cane, and suitable use of fertilizers. Thus the future for sugar production in Cuba still is bright.

However, recent events in Cuba well illustrate the extent to which, in our modern world, political conditions may interfere with the free flow of trade, changing the trends of development of a flourishing industry. Up until 1960 Cuba was the principal overseas supplier of cane sugar to the United States, with the Cuban sugar quota amounting to about one third of American domestic requirements in the later years. The regime that took over power in Cuba after 1959 encouraged trade with the Communist countries, and the hostility of this regime toward investments of and trade with the United States caused suspension of the American sugar quota. As a result of a smaller market, lack of production incentives in Cuba, and changed management of production, output diminished considerably after 1961.

Another example of the effects of political conditions is Indonesia. Sugar cane can be grown successfully in the low coastal and interior plains of the central and eastern portions of Java, where a dry season, the "east monsoon," will insure the necessary concentration of the juice. Under the former Dutch regime land was rented from the natives for limited periods of time, and sugar was produced on a highly scientific, highly intensive basis, with yields per acre far exceeding those of the other major producers. The exports of sugar brought outside money into the economy. However, Java is much more densely populated than Cuba, and the pressure for additional food-crop acreage was, therefore, very great. During World War II the sugar industry was completely lamed, and many of the mills fell into decay or were destroyed. Land formerly used part of the time for sugar cane was then devoted exclusively to food crops. The revolution which followed Japanese occupation led to an independent Indonesia, but not to a revival of the sugar industry. Java, once one of the major producers for export, is no longer a factor in the world's sugar market. Whether it ever will be again appears doubtful, at least at this time.

Among the other producers of cane sugar in the Western Hemisphere should be mentioned Hawaii, Puerto Rico, the Dominican Republic, Peru, Brazil, and Argentina.

The Hawaiian Islands have an oceanic climate with rather moderate temperatures, so that the cane requires a growing season of 20 to 24 months. On the northeast or windward side of the islands precipitation is abundant, while on the dry leeward side the scanty rainfall must be supplemented by irrigation. The rugged topography has

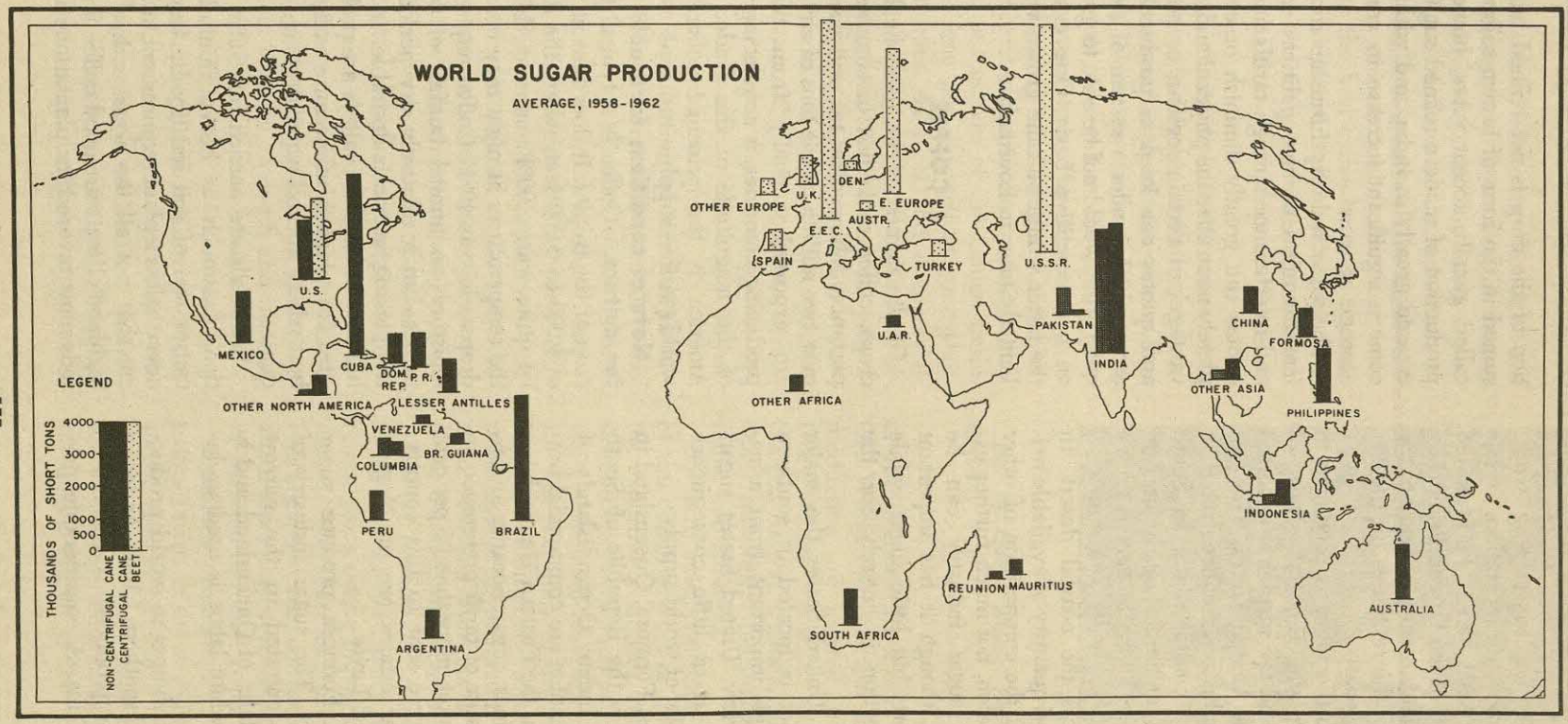


Fig. 95. World production of non-centrifugal sugar, centrifugal sugar, and beet sugar. Non-centrifugal sugar has been expressed as centrifugal sugar by applying a conversion factor of 79/96.

necessitated expensive engineering works for irrigation and transportation, while much of the labor has had to be imported from various parts of the Orient. Practically the entire Hawaiian sugar crop is sent to the U.S. mainland, to the refineries on the Pacific and Atlantic coasts.

In Puerto Rico the sugar is produced in the low coastal plains, especially those of the north coast, and the surplus is exported principally to the United States. The Dominican sugar industry is concentrated in the low southern coastal plain. In South America, Peru is an important sugar producer and exporter. There the cane is grown under irrigation in the valleys of numerous rivers which cross the coastal desert. In view of the limited quantity of available irrigation water and the competition of other crops, such as cotton, not much further expansion of the sugar industry can be expected. Brazil, though it has important production, exports but little sugar, while Argentine production is entirely for the domestic market.

In continental United States the major sugar-cane district is located in southern Louisiana. Though important from a national point of view, United States sugar-cane production is of little consequence from the standpoint of world supply.

The Philippines, Formosa, Queensland in Australia, Natal in the Republic of South Africa, and the Indian Ocean islands of Mauritius and Réunion are commercial producers of sugar in the Eastern Hemisphere.

In the Philippines, sugar became an important crop because of tariff preference on the American market; more than 95 per cent of the exports were sent to this country. The largest sugar estates are on Negros, Cebu, Luzon, and Leyte.

Mauritius and Formosa produce sugar chiefly for export. The sugar industry of Australia is concentrated in the narrow eastern coastal plains of Queensland and is unique because white labor is used exclusively.

Important contributors to world production are India and southern China. As far as quantity of sugar produced is concerned, India outranks Cuba. A considerable portion of the crop is not refined but is consumed in the form of brown sugar, the so-called gur. In recent years, however, the production of modern refined sugar has increased greatly in India, and with this has come a significant increase in commercial acreage of cane.

The sugar industry furnishes some excellent examples of how political conditions and interference through tariffs and import quotas can greatly diminish or even completely neutralize the physical and other advantages of certain regions, or how tariffs and quotas can keep in production other areas which, under a system of really free enterprise, would not be able to grow sugar on a competitive basis. One example of the latter would be cane grown within the United States in Louisiana.

COFFEE

Of the numerous nonalcoholic beverage crops, coffee ranks first in commercial importance, followed by tea and cacao. Well over two million metric tons of coffee beans are exported annually from the major producing countries, a convincing measure of the magnitude of this trade. Tropical America is the principal source of the world's coffee supply.

Natural conditions favorable for coffee culture. Coffee is a typical highland crop of the tropics. It does best at altitudes of 1,000 to 6,000 feet, where the days may be quite warm, 90°F. or more, but where the temperatures at night may occasionally drop as low as 40°F. Coffee requires much moisture—an annual rainfall of 50 to 90 inches—but a relatively dry period during the picking season is desirable. In general, hillsides rather than valleys are preferred as sites for plantations because coffee grows best where air and water drainage are adequate.

Rich soils are needed for coffee production. Inasmuch as heavy rainfall, which causes loss of soil fertility by leaching, is nevertheless a plant requirement, it is apparent that not all the areas with a tropical highland climate are good coffee lands. The soils most favored for plantations are those

of volcanic origin, where weathering is actively breaking down lavas and liberating the essential plant foods. The finest coffee lands of Brazil, Colombia, Central America, Mexico, Java, and Sumatra all have rich and deep loamy soils derived from young volcanics. On the best coffee lands in Central America and Brazil, the mantle rock, the weathered material upon which the soils are formed, is said to reach depths of over a hundred feet.

Although many species of trees and shrubs belong to the genus *Coffea*, only a few have been found suitable for coffee production. These are *Coffea arabica* and *Coffea robusta*, both tall shrubs, and *Coffea liberica*, a small tree. The first named is probably a native of Ethiopia and grows best in tropical highland areas, whereas the latter two are natives of the Congo basin and of Liberia and do well at somewhat lower altitudes. Most of the commercial coffee crop of the world is a product of different varieties of *Coffea arabica*, prized because of the superior flavor of the beverage made from the beans of this species. *Coffea robusta* (Fig. 96), because of its resistance to fungus diseases, is grown extensively in Indonesia, while some *Coffea liberica* is still grown in Africa.



Courtesy Official Netherlands Information Bureau in U.S.A.

Fig. 96. Coffea robusta. Plant with berries and flowers.

Present distribution of the coffee industry. From its original indigenous home in the highlands of Ethiopia, coffee culture gradually spread to Arabia, India, Indonesia, and the Western Hemisphere. The early Red Sea port of Mocha, from which coffee first was introduced to Europe, and the later center of production in Java have left their names in coffee terminology. After about 1880, however, fungus diseases destroyed most of the Javanese and Ceylonese plantations, and the cultivation of *Coffea arabica* became unprofitable in the East. The chief centers of production shifted to their present location, in South and Central America, the West Indies, and, more recently, Africa (Fig. 97).

At present, the commercial crop of the New World comes largely from the well-watered highlands of southeastern Brazil, Colombia, Venezuela, Central America, southern Mexico, and the higher slope lands of Haiti, Puerto Rico, and Jamaica. In the Old World the principal regions of coffee production are located in Indonesia, the Ivory Coast, Angola, Madagascar, the Congo, Kenya, Uganda, and Tanganyika. Small quantities are produced in Yemen, India, and Ethiopia.

South America contributes about one half of the coffee exports of the world. Among the exporting countries, Brazil easily ranks first, although its fraction of the total world exports declined from about 75 per cent in 1906 to less than 40 per cent in the early 1960's. Colombia in recent years has furnished about 15 per cent of the total coffee exports. Other exporters of note are Guatemala, Mexico, and Venezuela.

Coffee production in Indonesia, which formerly held third place, has been low in recent years, owing to postwar political conditions. The share of Africa in the world's coffee exports has increased steadily from about 5 per cent in the early 1930's to about 25 per cent in recent years.

Brazilian production is still the dominating factor in the world's coffee markets. In the state of São Paulo the light green of the plantations is the most conspicuous feature of the cultural landscape. The principal producing region is the southeastern pla-

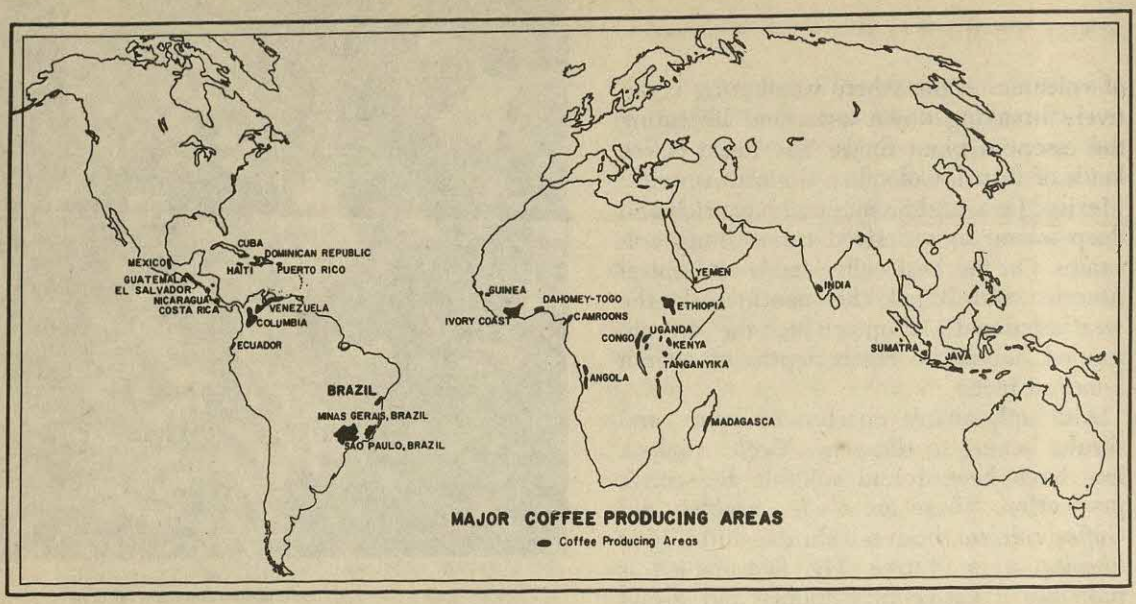


Figure 97.

teau, a highland area which slopes westward from the Coast Ranges toward the Paraná river in the interior, particularly in São Paulo and adjacent sections of Minas Gerais. On this plateau, at altitudes of 1,000 to 2,500 feet, are thousands of square miles of rich, red soil of volcanic derivation capable of producing several times as much coffee as the world needs. The rainfall, about 60 to 75 inches per year, is favorably distributed, the major part occurring during the growing season of the coffee berry. The cool period of the year, May to September, is relatively dry and is the ripening and picking season. The coffee crop begins to reach maturity early in May, and picking lasts until September. Inasmuch as coffee picking can be done only by hand, this one-period harvest involves a greater need for labor than do harvests where the ripening period is more prolonged, as is the case in some of the regions of northern South America (Fig. 98).

Since coffee is the principal support of a large part of the population of Brazil, it is obvious that failure of the crop or a prolonged period of overproduction will result in economic distress.

Because of the large profits formerly realized by the Brazilian growers, the acreage in coffee plantations was enormously increased. Lack of careful study of potential market demands and lack of planning in accordance with demands led to overexpansion, overproduction, and disastrously low prices. The Brazilian government therefore resorted to a system of price control, buying up large stocks of coffee with the idea of holding them until prices improved and then releasing them gradually. In its earlier stages, this so-called valorization scheme met with considerable success. Soon, however, the artificially sustained Brazilian prices made it profitable for other countries to increase coffee production. The accumulated Brazilian surpluses could not be absorbed by the existing markets, little was done to develop new markets, and for years it was considered necessary to destroy large stores of coffee without any return. The attempts of any single nation to increase prosperity through a permanent policy of destruction seems doomed to failure in the majority of cases and, in addition, hurts the world standard of living. Planning through international cooperation on a sound economic basis is necessary even where one country holds such undisputed leadership in production as Brazil holds in coffee.

Every country of the Western Hemisphere from Paraguay to southern Mexico produces some coffee. Production has been increasing in the highlands which extend from Venezuela and Colombia through Cen-

tral America into southern Mexico, because of the favorable soil and climatic conditions and the fine-flavored coffees grown there. Increased plantings have been fostered by the high price of coffee, the low prices of suitable land, and the accessibility of the American markets. It seems probable that further expansion will occur in these regions.

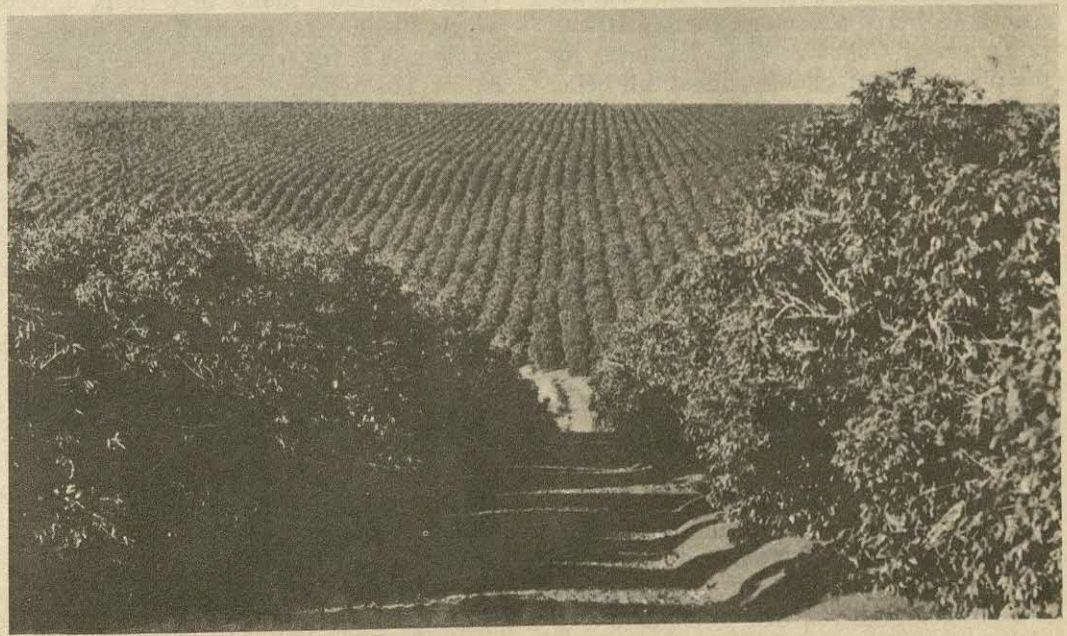
Commercial production is also important in the Greater Antilles: Cuba, Haiti, the Dominican Republic, Puerto Rico, and Jamaica. Haiti has a well-developed market in France because of former colonial ties. Cuba can expand her production, although sugar has been in a better competitive position and hence has received principal attention. Puerto Rico is favored by an abundant labor supply and close trade connections with the United States. The Blue Mountain coffee of Jamaica has the reputation of being equal to the world's best and commands a premium in European markets.

In the Eastern Hemisphere, Indonesia led in export trade before World War II. The coffee is grown mostly in the mountains of eastern Java and western Sumatra, chiefly between altitudes of 1,000 to 3,000 feet. The principal species planted is *Coffea robusta*, because of its resistance to fungus diseases, although in a few districts *Coffea arabica* is still grown. In Arabia coffee is produced under irrigation in the coastal kingdom of Yemen. Arabian coffee is considered to be of superior quality and generally commands high prices, as does coffee from Ethiopia. Coffee from both of these producers enters into the trade as Mocha.

International trade in coffee. For a long time the world trade in coffee flowed principally from the West Indies and Indonesia to Europe. Now the world's chief coffee stream is from Santos and Rio de Janeiro in Brazil to New York in the United States, with lesser streams from Cartagena and Puerto Colombia in Colombia to New York. Other streams run from the various Latin American producers to Europe (USSR not included). Before World War II, Europe accounted for between 40 and 45 per cent of the world's imports of coffee. Imports, of course, decreased greatly during the war, but they have regained their old levels.

Fig. 98. General view of a large coffee plantation in Brazil.

Courtesy Merrill Lynch, Pierce, Fenner, and Smith



Over half of the coffee exports of the world go to the United States, where consumption has risen from 3 pounds per capita in 1830 to an average of over 15 pounds in the early 1960's. Since half of the United States imports come from Brazil, the commercial and economic ties between the two countries are close. The increase in imports from more northern tropical countries, owing to a preference in the United States for a larger admixture of mild coffees in the blends, has slightly reduced the percentage received from Brazil.

Coffee has attained mass appeal as a beverage over the past century or so. There are many varieties of beans and many methods of roasting the bean. Rather light roasts provide the common coffees for consumption in the United States, but other styles are coming into use. The darker and heavily sweetened Turkish style coffees are found in Greek and Turkish restaurants, still darker French roasts and the nearly charred Italian styles are found in "Espresso bars" and are brewed into extremely hearty beverages.

A recent trend in coffee consumption which has implications for tropical producers is the use in the United States and Western Europe of soluble or instant coffees. This product employs as raw material the stronger-flavored types of coffee and has tended to be of advantage to the African producers of *Coffea robusta*. Factories for the production of soluble coffees are being built in the tropical coffee-producing nations, for example, in the Ivory Coast.

SPICES

In the minds of many inhabitants of the middle and high latitudes, spices are more intimately associated with the tropics than are any other products. This association of ideas is, however, chiefly a survival of times past. The spices now constitute a very minor portion of tropical products entering world trade.

In many tropical countries the food of the natives is highly seasoned. Spices have been known and used for untold centuries in the warmer regions of the earth. Whether this is a physiological response to climatic conditions or whether it is the result of the tastelessness of the native diet, particularly of rice, remains an open question.

Even in pre-Roman times small quantities of spices reached the Western world and, according to some, became immensely popular among the rich because of the often doubtful quality of the meat in a region with hot Mediterranean summers and no means of refrigeration. The later famous spice trade was partly responsible for the wealth of Venice and Genoa, for the discovery voyages of the Portuguese and Spanish, and for the foundation of colonial empires, such as those of Portugal, Great Britain, and the Netherlands. Spices were compact and very valuable, and they kept well. They were therefore eminently suitable for an early trade, which could deal only in luxuries because of slow, hazardous transportation and the small size of a camel's load or even of a ship's cargo.

Most of the spices which once brought their weight in gold are now common kitchen ingredients, and, although they have lost their dominant place in trade with the tropics, the volume of shipments of many spices is vastly greater than it was in the sixteenth and seventeenth centuries.

Distribution. Among the spices, *pepper* (*Piper nigrum*) stands first. It is a vine which, like ivy, fastens itself to a support—a pole or a living tree with not too dense a crown. The pepper plant can be grown only where temperature and humidity are constantly high. The fruit is a red berry which grows in bunches of 20 to 50; each berry contains one seed, the real peppercorn. If picked green and dried, the berries become dark and wrinkly, the pericarp adhering to the seed. This is the so-called black pepper. In white pepper the pulp has been removed from the seeds (Fig. 99).

Sarawak, India, and Indonesia are the world's principal suppliers of black pepper. Smaller quantities are exported from Ceylon, Indochina, Malaya, Thailand, Malagasy, the Congo, and Brazil.

India produces small amounts of pepper on the warm and humid Malabar Coast, the "Pepper Coast," which was one of the principal goals that led Vasco da Gama



Fig. 99. A pepper garden in the Lampongs region of Sumatra, Indonesia. Pepper is a vine. The berries are first green, then red, and yellow when they are ripe. After picking they are dried on mats in the open air and turn black.

Courtesy Indonesian Information Office

to make the first direct sea voyage from Europe to the Orient.

Cloves are the dried flower buds of a tropical tree (*Eugenia caryophyllata*) found originally in wild state in the Moluccas, or Spice Islands. During the seventeenth and eighteenth centuries the Dutch had a virtual monopoly on the trade in cloves. At present, most of the cloves entering world trade are produced on the little islands of Zanzibar and Pemba, on the east coast of Africa, which enjoy a warm and very humid climate.

Cinnamon is the inner bark of a small tree (*Cinnamonum zeylanicum*), which is cultivated in Ceylon and Java. Closely related to the Ceylon cinnamon is cassia, a product of wild or cultivated varieties of cinnamon trees which grow in India, Indonesia, Indochina, and southern China. In quality it is inferior to the Ceylon product, but it is often used as a substitute.

The *vanilla* plant is an orchid which entwines itself around trees. Because it needs dry weather during the flowering period, it is best adapted to the marginal areas of the tropics, where pronounced dry seasons prevail. The principal producers of vanilla are southern Mexico, Réunion, the humid north and east coasts of Madagascar, and neighboring islands. In recent years the industry has suffered greatly from the competition of synthetic vanilla, which has a much stronger flavoring power than has natural vanilla.

MEDICINAL PRODUCTS

The tropical regions are important sources of a number of medicinal products, among which *quinine* is undoubtedly the most valuable. In many parts of the world quinine and mosquito netting are practically the only means of combating that great scourge of humanity, malarial fever. Quinine is extracted from the bark of the cinchona tree, which grows wild in the forests of the eastern slope of the Andes Mountains. It is a tree of the tropical highlands, occurring mostly at altitudes between 3,000 and 8,000 feet. As a result of the inaccessibility of the Andean forests and the destructive methods formerly practiced by the native searchers for bark, there has developed a plantation industry whose output has almost entirely superseded that of the wild tree. This industry centers in Indonesia, especially on some of the mountain slopes of western Java. Apart from Indonesia, cinchona plantations are found in India on the slopes of the Himalayas and at Madras, while small quantities of South American cinchona still reach the principal markets.

The leaves of the *coca bush* (*Erythroxylon coca*), which is grown on the eastern slopes of the Andes between elevations of 2,000 to 5,000 feet, are chewed by the Indians during work and on the march. The stimulating effect of the leaves is due to their content of cocaine, a drug indispen-



Fig. 100. There are many excellent tropical fruits that rarely reach higher latitudes. A picturesque fruit tree is the papaya. The fruit resembles a long melon, bright yellowish to greenish in color. The juicy flesh has an orange tint, and contains papain.

Courtesy Indonesian Information Office

sable to the medical profession, but dangerous and habit-forming when wrongly used.

TROPICAL WOODS

One of the great resources of the areas of rainy tropical climate are the immense tropical rain forests which cover with a heavy mantle of everlasting green so much of northern South America, Central Africa, and the Australasian archipelago. These forests, in contrast to most of those in higher latitudes, consist almost entirely of hardwoods. Softwoods, that is, coniferous trees, grow in some places, particularly on plateaus and higher mountain slopes, but their total acreage is small in comparison with that of the hardwoods. (See Map of World Vegetation, p. 108.)

The tropical rain forests have no prolonged annual period of rest. Conditions throughout the year are so favorable for assimilative processes that many species do not show the pronounced growth rings which are so typical of the trees of the middle latitudes. Many tropical woods have a fine, even texture, and some are remarkably hard and heavy. Various types of so-called iron woods, with a specific gravity greater than that of water, are common throughout the rainy tropics.

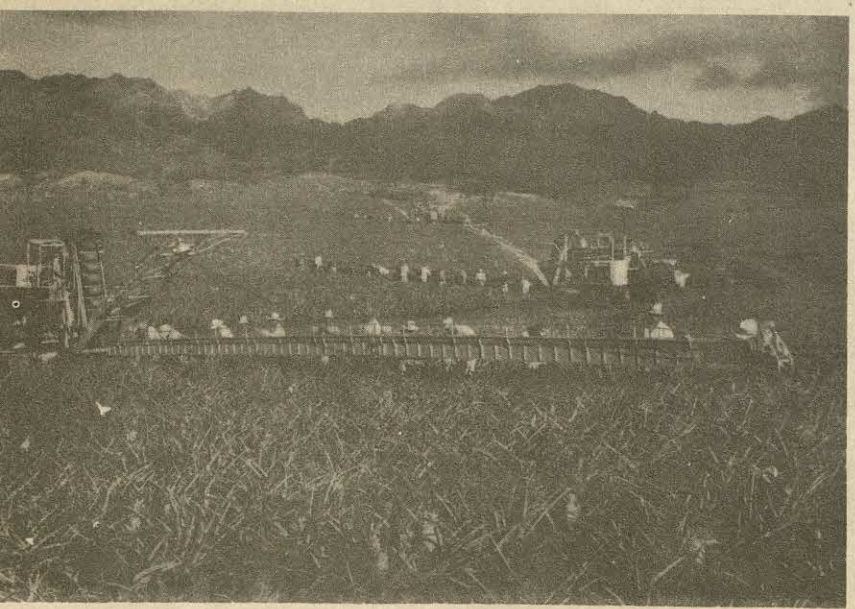


Fig. 101. Old methods of hand-harvesting a tropical product. This photograph shows the application of the most modern techniques to the harvesting of pineapples in Hawaii. Each machine can harvest 25 tons of fruit per hour. Certainly much can still be done to bring more tropical products within economic reach of inhabitants of the middle latitudes.

Courtesy Libby, McNeil and Libby.

Commercial production. Notwithstanding the excellent quality of some of the wood, only a very small percentage of the tropical timber resources is commercially exploited at the present time. In a few regions agriculture, in its search for new virgin croplands, is making extensive inroads into the rain forest. Such is true, for example, in the cacao districts of Ghana, where the former British colonial government considered it necessary to set aside parts of the tropical forest as permanent reserves. Nevertheless, the tropical rain forest is a reserve of timber which is relatively untouched.

For several reasons the tropical hardwood forests have not gone the way of most of the hardwood, and a considerable part of the softwood, forests in Europe and North America. In the rain forest, although they are not completely absent, pure stands of trees rarely occur. In an acre of tropical forest one will find, as a rule, dozens of different species of trees. Such greatly mixed stands seriously handicap commercial exploitation. It is often impossible to find more than one or two trees of the kind one is looking for in an acre of tropical forest—mahogany trees being often even scarcer than that. Thus long haulage ways have to be opened up in the forest. Furthermore, a certain percentage of the timber, because of too fast growth, may be of rather poor quality, with coarse or uneven texture. To this must be added numerous difficulties of a physical nature: unhealthful climate, sometimes troublesome undergrowth, and soft, swampy ground. As a result, the cost of moving logs or sawn timber overland within tropical forest areas is very high. As an illustration of how high this cost is, port cities in the tropics can often obtain softwoods for construction work cheaper from the northern coniferous forests of Scandinavia or Canada than they can obtain equally suitable woods from the tropical forests in their own hinterland. After timber has been moved to the port cities, it is still a minimum of several thousand miles from the nearest middle-latitude markets, a circumstance which further adds to the cost of marketing the product.

Under such conditions, and as long as great quantities of timber for ordinary purposes can be cut at relatively low cost in the middle latitudes, the utility hardwoods and the few softwoods of the tropics cannot compete in world markets. Only those woods which have special properties of grain, color, hardness, or fragrance, such as cabinet woods used in the manufacture of high quality furniture, or other woods with specific properties of lightness, softness, etc., have sufficient value to be worth exploitation and transportation to middle-latitude markets.

The handicap of high transportation costs has recently been overcome, at least in part. During the 1950's and early 1960's veneer and plywood factories were being set up in or near some of the tropical forest areas to process certain local types of timber. The semifinished products which are then exported have a higher value and can better carry the costs of shipping to the markets in the middle latitudes. A considerable number of tropical woods, under greatly varying names, reach the Western markets. One further handicap to the trade in tropical woods is that, from a botanical point of view, the forests are still imperfectly known; wood of widely different species of trees may have similar popular or trade names and similar appearance, yet have greatly different properties.

Some of the precious and semiprecious woods have been made the objects of wide search, and their names have become familiar in most of the Western world. Mahogany and ebony rank foremost in this respect.

Distribution. True *mahogany* (*Swietenia*) is much sought after for fine cabinet work. It is moderately hard, has a beautiful grain and a rich color which improves with time, and can be applied as a veneer. It occurs only in southern Mexico, Central America, the West Indies, and northwestern South America. Mexico is an important shipper of mahogany, and Honduras and British Honduras have always been noted as producers of exceptionally fine types of this wood.

Several species of which the wood is sim-

ilar and to which the name mahogany is often applied, are closely related to *Swietenia*. Among the most important of these is the African mahogany (*Khaya ivorensis*) of the Guinea coast forests. The Ivory Coast is the principal exporter of this type of wood. Southeastern Asia also produces some woods that resemble true mahogany.

A type of wood that always conjures up pictures of tropical lands, is *ebony* (*Diospyros ebenum*). Ebony, slaves, and ivory once were the principal products of trade in tropical Africa, and ebony was sought after as early as the days of King Solomon. The wood is very hard, usually coal black, and exceedingly fine grained. The trees that produce it are found in Africa, Madagascar, and southeastern Asia. Several other woods closely resemble ebony and are often sold under that name.

Where accessible, the Honduras *cedar* (*Cedrela mexicana*) has been exploited to the verge of extinction. Cedar wood is reddish, soft, and fragrant. Especially because of its fragrance it is in great demand for the manufacture of cigar boxes. Cedar trees have a wide range, from southern Mexico to tropical South America. The cedar of the Far East (*Cedrela toona*) is closely related to the true cedar, and its wood is practically identical. Central America, Brazil, and Mexico furnish most of the tropical cedar now used.

Teakwood (*Tectona grandis*) is in great demand for its strength and durability. The teak tree does best where there is a dry season of several months' duration. It is found, therefore, most abundantly in the deciduous monsoon forests of southeastern Asia, especially in Burma, Thailand, eastern Java, and the Philippines. Since teak occurs in pure stands, it can be easily exploited. At present some of the principal stands of teak trees, such as the "djati" forests of Java, are under scientific silvicultural management.

Balsa wood (*Ochroma lagopus*) of the forests of central South America is one of the lightest of woods, ranging in weight from 4 pounds per cubic foot to about 24, nearly the hardness and weight of soft pine wood. For centuries this wood has been used for rafts. At present it has some specialized industrial applications and is used as a structural material by the thousands of young people who build and fly model airplanes.

Among the large number of other tropical woods may be mentioned *sandalwood*, *satinwood*, and *rosewood*.

Other important economic products of the tropical forests are the resins and nuts, the harvest of which in many of the more sparsely settled districts constitutes the principal source of cash income for the native population. Among the various kinds of resins, the best known are the hard copals and the soft copals or *damars*, furnished by a number of different species throughout the tropics. The hard copals are used extensively in the manufacture of varnishes. Among the nuts of the warm rainy forests the best known are tagua nuts, corozo nuts, and Brazil nuts. The first two furnish the so-called vegetable ivory used in the manufacture of buttons, while the latter is an edible nut in high favor in American and European markets.

Southeastern Asia is the principal source of *rattan*, the stem of a liana, used in the manufacture of chairs and cane seats for chairs.

CATTLE KEEPING

The predominant cattle type of the tropics is the humped zebu (*Bos indicus*), an animal which is well adapted to survival under the often rigorous tropical climatic conditions. Throughout southern Asia significant numbers of water buffalo (*Bubalus bubalus*) are also kept. Both the cattle and the water buffalo are used to pull plows and the two-wheeled carts still used in rural areas. On occasion the cattle are used as pack animals, and both cattle and buffalo are used for milk and meat.

Strong food taboos are operative in many parts of the world and have an influence on the use and definition of agricultural resources. In India and other Hindu areas of southern Asia cattle are sacred and are not to be killed or eaten. The cattle population of India is very large, amounting to



Courtesy Institut Français d'Afrique Noire, Dakar. Photo by G. Labitte

Fig. 102. Humpbacked cattle in Senegal, western Africa.

around 160 million or about 1 cow for every 3 people, and there are about 40 million buffalo—yet India is an area of precarious food supply. Cattle are a potential, largely unused resource. In contrast, the United States has a cattle population of 97 million.

The zebu cattle of the tropics, while hardy, are of low productivity with respect to meat and milk, compared to the cattle of the middle latitudes. While milk yields of 10,000 to 15,000 pounds per lactation are common in the Western world, yields ranging from 500 to 2,000 pounds are characteristic of cattle in the tropics. Beef cattle of a weight of eleven hundred pounds can be produced in less than 2 years in the United States, but in Africa and much of India it takes 5 to 6 years to produce beef cattle ranging in weight from 700 to 1,000 pounds (Fig. 102).

In the savannas of tropical South America—in Colombia, Venezuela, and Brazil—there are large herds of *Bos taurus* (middle-latitude cattle), which through the past several centuries have become semi-adapted to tropical conditions. However, the productivity of these animals is also very low. The middle-latitude regions of South America—southern Brazil, Uruguay, Argentina, and Chile—have large herds of highly productive *Bos taurus* cattle, and these regions are noted for the quality of the beef produced.

The tropical savannas of Africa contain immense herds of zebu cattle. These are largely hardy animals resistant to long periods of drought, continuous high temperatures, and to many, though not all, of the diseases which plague livestock in the tropics. An epidemic of rinderpest, or cattle plague, occurred around the turn of the century, and within a decade decimated herds from Cairo southward to the Cape of Good Hope. Most of the cattle of tropical Africa are also susceptible to trypanosomiasis, a disease analogous to human sleeping sickness. This disease is carried by the tsetse fly and occurs over large portions of the savanna lands. There are extensive tsetse-infested areas in many parts of West Africa and a number of smaller ones in eastern Africa; these are uninhabited because cattle keeping is not possible (Fig. 72).

While food taboos restrict the use of cattle for meat in India, other factors restrict their use in Africa. Here the main cattle-keeping tribes own 4 to 10 cattle per person, yet little meat is eaten. Among the reasons for this is the idea held by many tribes that cattle are a form of insurance against complete famine. They are the only available food supply which can, in effect, be stored "on the hoof," and thus be kept for emergencies. During a prolonged drought and resulting famine the cattle that die are eaten, and, as a last resort when other food supplies are exhausted, live cattle are killed and eaten. This is not to convey the idea that cattle are never butchered in time of plenty. They are, but only on a small scale.

In Africa cattle are used on a sustained-yield basis, which is consistent with the notion of cattle as insurance. Milk is used among many, though not all, tribes (there are taboos against milk drinking, too), but the amount used is not large because the unimproved African zebu yields only 300 to 600 pounds of milk per lactation. Note the difference between this and the yields from European cattle cited earlier. Tropical cattle, while hardy, are of low productivity.

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10

The Regions of Dry Tropical Climates

areas of limited agricultural potential

A CLIMATE may be classified as *dry* wherever the rainfall is not sufficient to support tree growth on the uplands. Although other factors, such as highly permeable gravelly and sandy soils, may contribute to the absence of trees, aridity is the fundamental cause for the existence of most of the treeless areas in the warm climates. As pointed out in preceding chapters, a rather wide zone on both sides of the equator has essentially very humid to humid climates. On each side of this zone, in latitudes roughly 20 to 30 degrees north and south of the equator, lie belts where little rain falls. (See World Map of Climatic Regions and Fig. 103.) These dry belts, crossed by the Tropics of Cancer and Capricorn, are often referred to as the tropical desert areas. The middle portions are extremely dry, in places almost rainless. They are bordered by semiarid belts which mark the transition to the more humid climates on either side. Equatorward lie the tropical savanna areas, while poleward lie mostly areas of Mediterranean climate. On the basis of the occurrence of low winter temperatures, considerable portions of the poleward sections of the dry tropical climates (4 and 5 on map at end of book) should really not be included with the tropical climates. For example, even though the Sahara Desert is one of the hottest regions in the world, in the northern portions of the desert winter temperatures may drop below freezing point at night and even during brief periods in the daytime. Frost occurs practically every winter in such northern oases as Touggourt and Ouargla and is not unknown as far south as In-Salah. With increasing altitude, winter conditions can become very uncomfortable indeed. For example, at Tamanrasset, located in the Ahaggar Mountains at an altitude of about 5,000 feet, as many as 14 consecutive days of frost have been observed with a minimum temperature of 20°F. A French expedition sent to the Tassili area, north of the Ahaggar Mountains, to copy ancient rock paintings, worked at an altitude of slightly over 5,000 feet and encountered freezing temperatures in December and even several inches of snow in January. On a trip through north-

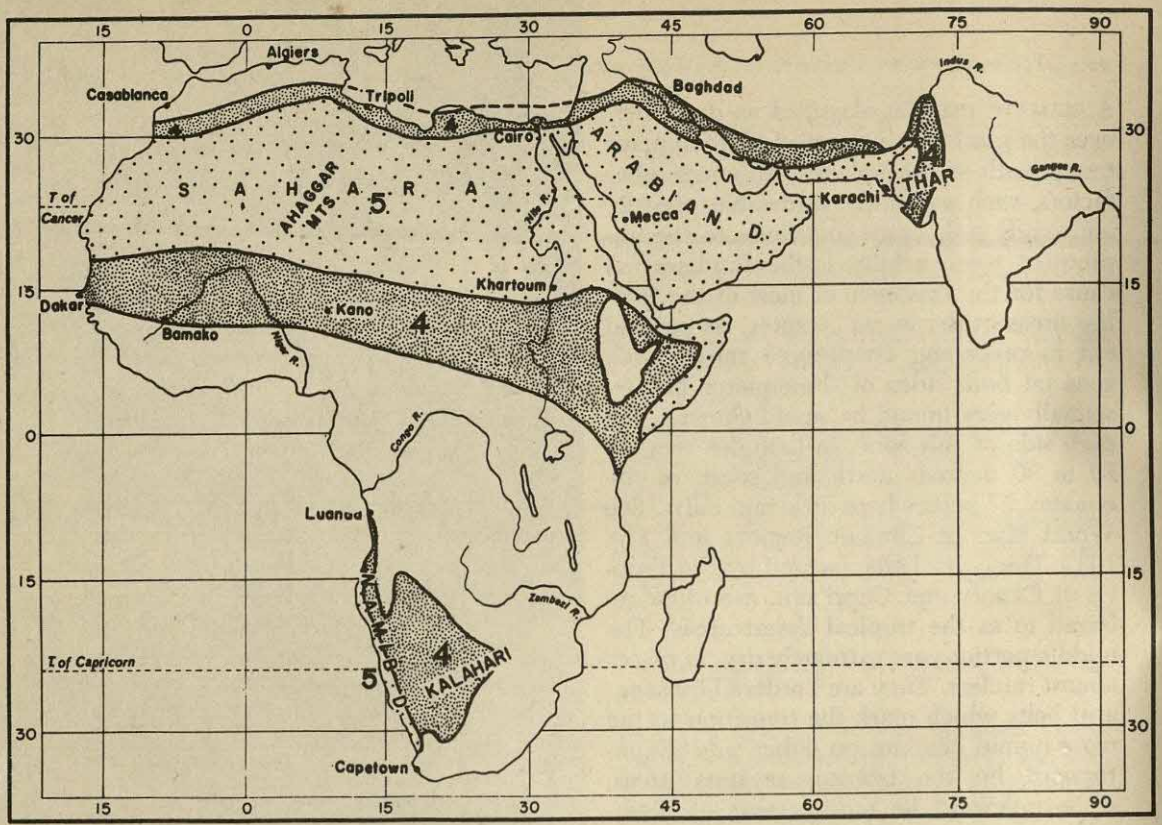


Fig. 103. Regions of dry tropical climate in Africa and adjacent parts of Asia. 4. Tropical steppe climate. 5. Warm desert climate.

western Saudi Arabia, H. St. J. Philby, one of the noted explorers of Arabia, encountered in January minimum temperatures of 20° to 25°F on the Hisma Plateau.

However, the overriding climatic factor in these regions is aridity, not temperature, and whatever significant differences exist within the area are due to differences in the degree of aridity. Thus, for the purposes of this book there would be little advantage in dividing these dry regions into tropical and nontropical.

From a causal point of view, the semiarid to arid conditions near the Tropics of Cancer and Capricorn and the heavy rains in the equatorial regions are associated with differences in atmospheric pressure. While the equatorial belt is characterized by comparatively low pressure, ascending air, and heavy rainfall, in the high-pressure belts along the Tropics of Cancer and Capricorn the air generally has a tendency to descend, and little rain falls.

In western South Africa and South America rainfall is lowest near the coast. Here lie the long, narrow desert strips of the Namib Desert in the former, and of the Atacama Desert and the Peruvian-south Ecuadorian coastal deserts in the latter. Winds are almost continually from land to sea and, being part of the trade-wind system, bring no moisture. Besides, these shore winds from the land drive the warm surface water away from the shore, allowing much cooler water from greater depth to well up. This, plus cool, along-shore currents from polar latitudes, further aggravate the situation. No wonder that in the Atacama Desert highly soluble nitrate deposits could accumulate and persist.

Where the rainfall is so low that it can support only bunch grasses and thorny bush, sometimes interspersed with a few scattered, hardy, drought-resisting trees, the climate is classified as semiarid. Where rainfall is so slight that perennial vegetation is sparse or

wanting, where the annuals are dormant most of the time and the landscape takes on the color of the rock (be it pinkish or blackish, yellow or brown), there is the desert, a product of the arid type of climate. Although the amount of annual rainfall is not a reliable criterion, since magnitude of potential evaporation should also be taken into account, it may be said that the deserts of the tropical zone generally have less than 6 inches of rain per year, while the semiarid lands receive an average annual rainfall of 6 to 35 inches. In the desert it rains very infrequently, and the landscape acquires a greenish tinge only for brief periods following such rare showers. In semiarid lands, where the rainfall is somewhat heavier, the short grass or scattered shrub vegetation presents a green landscape regularly for a few months each year.

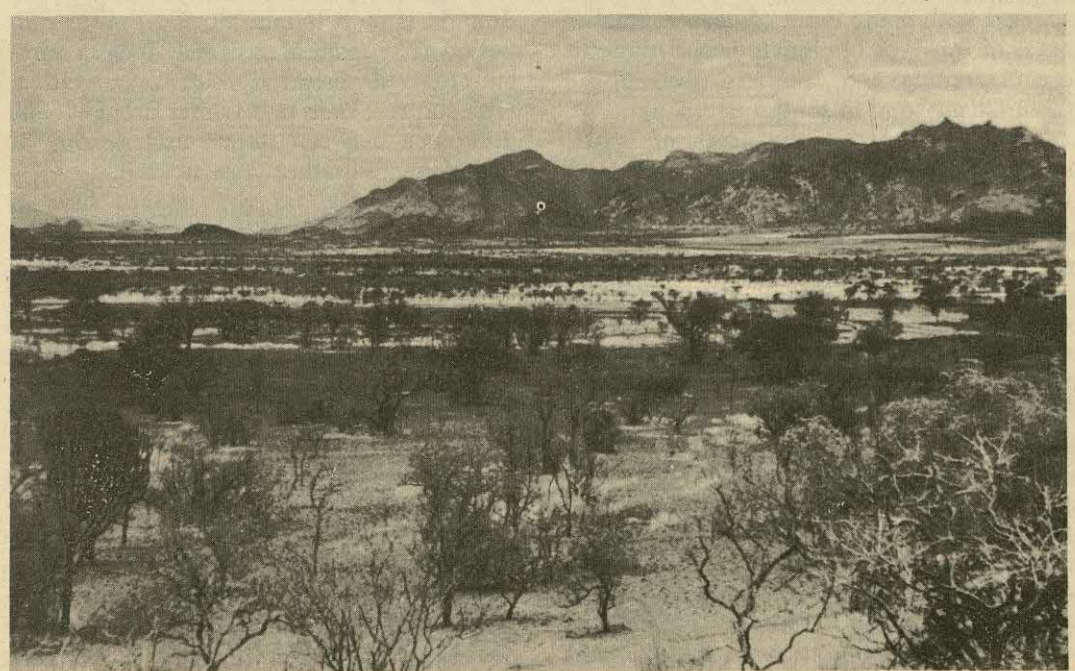
Inasmuch as low rainfall is the critical factor in arid and semiarid lands in both the low and the middle latitudes, it seems advisable to use a nomenclature that clearly reveals this fact. The term *desert* is universally used as a term for very dry lands in all latitudes. It seems justifiable to use the term *steppe* in similar manner for semiarid lands, whether they occur in middle or in low latitudes, even though the term referred originally to the short-grass vegetation of semiarid southern Russia (Fig. 103).

THE TROPICAL STEPPES

The largest areas of warm, semiarid lands are in Africa, where the Sahel of Tunisia, Algeria, and Morocco and the Sudanese Sahel and the Kalahari are prominent examples of this type. The Sudan steppe lands extend entirely across the continent, from Senegal and southern Mauritania in the west to Somalia in the east. Although varying considerably in their aspects from place to place, they possess the common characteristic of a native flora of short bunch grasses and scattered to dense thorny bush

Fig. 104. Tropical steppe landscape in northern Uganda, Africa. The short grass is dark where it has been burned over, light-colored where it has not. The trees are scattered, misshapen, and usually thorny.

Photo by Walter Deshler



or other xerophytic plants; near permanent and intermittent water courses may be stands of trees of varying density (Fig. 104). South ward the Sudan steppe merges imperceptibly into the tropical savanna lands with more trees, taller bush, and taller grasses; northward it merges into the empty desert. The narrow belt of steppe lands of North Africa continues eastward into Iraq, Iran, Pakistan, and northwestern India. Parts of these areas experience some cool to cold weather during the winter months. The Kalahari ranges from a grass steppe in the southern section to mixed acacia, bush, and grass in the central part. Westward it merges into true desert, the Namib, while northward it merges into the dry deciduous forest lands of Angola and Northern Rhodesia.

In Australia the semiarid belt borders the arid interior, being the transition zone between the rainier coastal strips and the almost rainless interior. In South America the most extensive area of warm, semiarid land lies in eastern Brazil, where considerable portions of the northeastern states, such as Piauí, Ceará, Pernambuco, and Baiá suffer from insufficient rainfall. Here the native vegetation is the *caatinga*, a low, open forest of frequently stunted trees, interspersed with many types of cactus. Smaller areas of this type of climate occur in northern Argentina and southern Bolivia—the Gran Chaco—and in southwestern Ecuador.

In North America the areas of warm, semiarid steppes include parts of Lower California and of the plateau of Mexico. (See World Map of Climatic Regions at end of book.)

Since the larger areas of warm, semiarid steppes are in Africa and Australia, the discussion which follows is based on conditions there. In North and South America conditions are broadly similar, but differ in detail.

General characteristics. The most prominent features of the warm, semiarid type of climate are the low annual rainfall, usually less than 35 inches, often less than 25, and its distinctly seasonal distribution (Figs 105 and 106). The dry season lasts from six to nine months, with some months

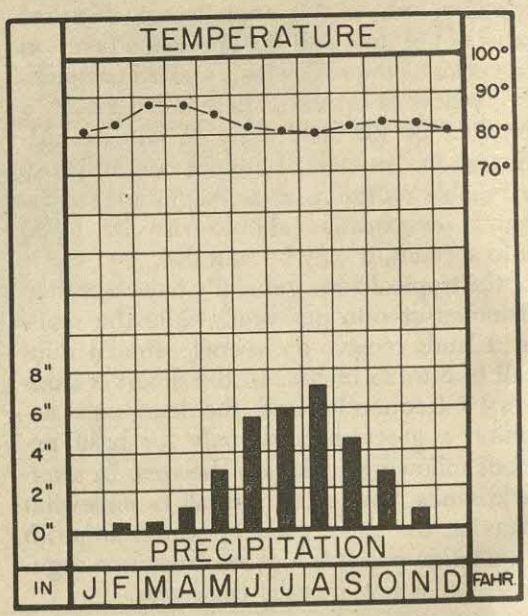


Fig. 105. Tropical steppe climate. Average temperature and precipitation, Hillet Doleib, near Malakal, Sudan. Altitude 1,283 feet, total precipitation 31 inches.

that are virtually rainless. In the areas on the equatorward side of the deserts the rainy season is generally associated with the high-sun period of the year, while the drought is most intense during the low-sun period. The tropical savannas have a similar seasonal distribution of precipitation, with summer rains and winter drought. The difference between steppe and savanna is one of degree rather than of kind.

Temperatures, on the whole, show a greater seasonal rhythm than in any of the more humid climates thus far discussed. This is due chiefly to the fact that the dry steppe lands occur at greater distances from the equator, although the greater dryness of the air is an important contributing cause. The hottest season of the year usually occurs during the high-sun season.

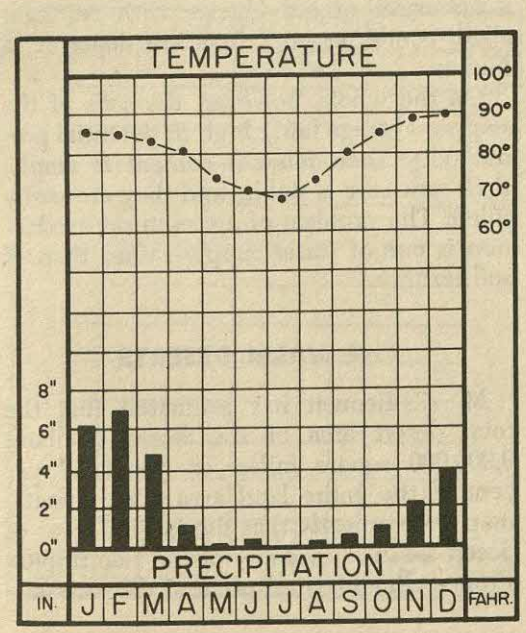
There is but little cloudiness to reduce the intensity of the sunlight, and high temperatures during the daytime are the logical result. At night, when there are no clouds to retard the escape of heat, radiation is rapid, and temperatures may become somewhat more comfortable. In northern

Africa maxima generally occur in August. South of the Sahara, however, the highest temperatures are registered in April and May, before the rains come, with a secondary maximum in September and October.

During the high-sun period the warm semiarid climates on the equatorward side of the deserts are characterized by variable winds and brief rains, sometimes of the convectional type or, as in West Africa, of the monsoon type. The rains are rarely of long duration, although they may be heavy. The period during which rains may occur lasts from three to five months. On the polar side of the deserts the rains usually occur during the winter season, as they also do in the adjacent areas of Mediterranean climate.

During part of the dry season in the northern Sudan, northerly to northeasterly winds prevail, blowing from the high-pressure area of interior northern Africa toward the low which lies along the Guinea coast, a strong local manifestation of the trade winds. Frequently very dry winds from the east to northeast, the so-called *harmattan*, give rise to a hazy, dusty atmospheric condition and to very high temperatures. According to Richard-Molard average maximum temperatures in April are 80°F. at Dakar, where the wind comes from the sea to the north, while 60 miles inland the average maximum temperatures run as high as 103°F. due to the influence of the harmattan. The harmattan may blow for weeks on end in the Sahel and parts of the northern Sudan. At Ségou, for example, on the upper Niger river, average April maxima are 108°F., and at Kayès even 111°F. In northern Africa a similar dry wind from the desert, which may blow from a few days to a week or even longer, is called the *sirocco*.

Fig. 106. Tropical steppe climate. Average temperature and precipitation, Daly Waters, Northern Territory, Australia. Altitude 633 feet, total precipitation 26 inches.



However, the trade winds mentioned above bring more moderate temperatures, especially from November to February. Although the weather conditions in areas of this type of climate are sufficiently varied to prevent the enervating monotony of the humid tropical type of climate, they can hardly be called pleasant and agreeable. Malaria comes with the wet season, and the parching dust-laden winds of the dry season leave eyes sore and lips and nasal passages cracked and bleeding. Of the African Sudan it is said that each new season of the year one regrets the preceding season. High daytime temperatures, brilliant sunshine rarely obscured by clouds, hazy atmosphere laden with dust, dry parching winds, and little rain constitute a fair résumé of the prevailing weather of the semiarid tropical lands.

Native vegetation and animal life. The ground zone of vegetation is low, consisting of grasses and low xerophytic shrubs, either or both, with bare ground showing conspicuously in places. (See Fig. 104.) The grasses are mostly of the bunchy type with coarse stems, although in some areas fine short species thrive, providing forage for numbers of grazing wild animals, such as gazelles and antelopes. The ground zone of vegetation is surmounted in many places by scattered bush or even occasional small clumps of low, thorny trees, and the term "cat's claw," often used in describing them,

is truly expressive. In general the leaves are small and leathery, so constructed as to conserve moisture and at the same time carry on the processes of transpiration and tissue building. The root systems are shallow but extensive, thus being suitable for rapid absorption of such soil moisture as becomes available after the brief rains. On the uplands the landscape presents broad views when observed from low hills or other eminences. Although the water courses are dry most of the time, tree growth and thorny bush along them are plentiful because of the supply of ground water. These strips of bush may occasionally be junglelike in their density. The bark of the trees is usually thick, sometimes corklike, the leaves are narrow, and spines and thorns are numerous. The wood is generally hard, with twisted or gnarly structure, which makes it difficult to split or saw it into boards.

In most places the warm semiarid steppes have some sort of timber suited for such simple construction purposes as building huts for people and corrals for livestock. Acacias and various tree cacti are common and useful for such purposes. The fuel needs are not great, and the supply of tree and bush is usually ample.

The warm semiarid lands are natural grazing grounds. The native animal life is either fleet-footed or fleet-winged and thus is able to move rapidly and over long distances to obtain water. The exceptions, that is, those species that are not swift of foot or wing, are well protected by thick skin or scales, so that existence with little water is possible. The warm steppe is the land of the antelope family, which is able to subsist on the moisture found in grass and in leathery-leafed shrubs when other water supplies fail. Insect life is abundant. The warm semiarid lands of Africa, Australia, and of northern Argentina are noted as being the breeding places for hordes of locusts, which swarm into more humid sections during dry years, causing heavy damage to crops and native vegetation.

Soils. As the rainfall in regions of warm semiarid climate is insufficient to produce heavy leaching, many of the soils are comparatively rich in lime and other minerals, and therefore belong to the pedocalic group. In color these soils range from chestnut and brown to gray as desert conditions are approached. In some areas, where grasses are abundant, soils so dark as to resemble chernozems have been found. However, in a number of the regions with this type of climate there are extensive areas of eroded lateritic soils, often with exposure of a hard, metallic layer consisting mostly of iron and aluminum hydroxides, which may be the unfortunate heritage of a formerly warmer and moister climate. This is true especially in the Sudan and in northern Australia. Where leaching is slight, there is a tendency for sodium salts to become concentrated in the upper parts of the profiles of semiarid soils, this tendency being more pronounced as aridity increases. Where because of the topography the ground-water level is near the surface, saline or alkaline soils may occur.

Where rainfall is so low that near-desert conditions prevail, the soils are generally immature and very shallow because of incomplete chemical weathering and unfavorable conditions for organic activity. The colors are usually grayish, often light. Such soils are rich in mineral constituents—in many cases excessively so, with resultant alkali conditions—but they are deficient in humus.

On the whole, however, the soils of the steppes average fairly high in potential productivity; their mineral content is ample, their structure is stable, and they are easily tilled. The problem of agricultural production is one of water supply rather than of soil fertility.

THE WARM DESERTS

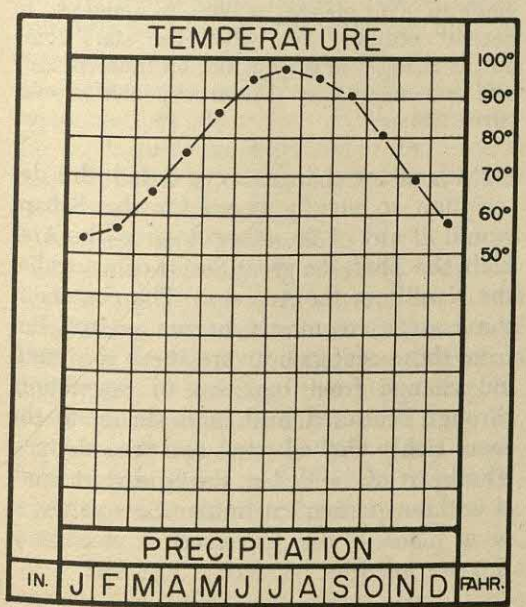
M. K. Bennett has estimated that the total desert area of the world is about 9,900,000 square miles, or about 17 per cent of the entire land area. The climatic map shows clearly that the largest areas of desert lie in the vicinity of the two tropics. From a climatological point of view we may

say that their location is poleward from the tropical semiarid lands and that the deserts constitute a sort of dry divide between the rainy lands of the low latitudes and those of the middle latitudes. (See No. 5 on World Map of Climatic Regions at end of book, and also Figs. 103 and 107, pp. 168 and 173.)

General characteristics. As stated at the outset of this chapter, the term desert is not limited to lands wholly devoid of vegetation. It also includes areas where the vegetation is dormant most of the time and where the landscape is characteristically brown, although occasionally rains may turn it into brilliant green and cause it to become flower-besprinkled for short periods. The true deserts are rocky, gravelly, or sandy wastes, but as ordinarily used the term is somewhat more inclusive.

The rainfall in the desert areas is very low. Over much of the Sahara it is less than 20 millimeters, or eight tenths of an inch per year, with only two small mountain areas, the Ahaggar and Tibesti, receiving as much as 2 inches per year. In much of the Mojave-Sonora desert area of North America average annual precipitation is less than 5 inches. At Yuma, Arizona, it is as low as 3.5 inches. Nevertheless, this area is considerably better watered than much of the Sahara, parts of the Arabian Peninsula, or the Atacama Desert of Chile. The rainfall is also irregular as to occurrence, and showers are often torrential. At a given place, months, even years, may elapse during which there is no rain whatsoever. Occasionally, however, sufficient moisture may be in the air so that, under the influence of rapidly ascending convectional currents, thunder clouds may develop, and heavy, sudden downpours result. Since life in the desert is adapted to aridity, great damage is sometimes done by such rains. A place which has had no rain for several years may receive three or four inches within a few hours. For a short time rain may fall in torrents, producing a veritable "cloudburst" which quickly inundates the flat lands, changes dry stream beds into raging water courses, and destroys earth houses in which the natives dwell. French soldiers stationed in the Sahara had strict orders never to camp in the *wadis* (the dry stream channels) because of the danger of sudden catastrophes of this kind. But the rainstorms are short-lived. The clouds quickly disappear, brilliant sunshine returns, and soon the landscape again presents the shifting hues of the desert.

Fig. 107. Tropical desert climate. Average temperature and precipitation, In Salah, Sahara. Altitude 1,080 feet, no precipitation recorded.



Temperatures and winds are subject to similar fluctuations. The changes in temperature from day to night are great, commonly as much as 40 or 50 Fahrenheit degrees. In winter night temperatures may occasionally drop close to or below the freezing point. This violent daily range is a source of discomfort to man and beast—roast at midday, freeze at midnight.

While the absolute humidity is often not particularly low, the average relative humidity commonly lies between 30 and 50 per cent and during the daytime may drop below 20. At Tamanrasset, in the approximate center of the Sahara, a minimum of 2.3 per cent has been observed! The evap-



Fig. 108. View in the Sahara near Ft. Charlet, northeast of the Ahaggar Mountains. Contrary to common opinion, much of the great desert areas consists of rock rather than sand. The white areas are sand plains.

Courtesy Government of Algeria

oration potential is enormous, as may be inferred from the low relative humidities as well as from the fact that sand temperatures of 140° to 160°F. have been found to occur at the surface. The occasional strong winds are perhaps the greatest source of discomfort—hot, low in moisture, laden with dust and sand, these winds parch the skin, crack the lips, and cause varying degrees of discomfort to man and beast. The hardships of travelers who encounter severe sandstorms are quite well-known, but it is not so generally understood that moderate winds rather than gales are most common in desert areas. The bare rock wastes or hot sands give rise to uneven pressure and unstable conditions in the lower strata of the atmosphere. Thus, currents develop, and the rapid movement of air near the surface from one place to another often gives rise to variable winds.

Where the desert reaches its full development as an expanse of bare rock (*hammada*), or as a sand and pebble plain (*reg*), or as areas of sand dunes (*erg*), where it is slightly friendlier to man, it always has associated with it the lure of the ever-changing aspects of the desert landscape. (See Fig. 108.) Thus, the desert has been the place where man could experience Nature's unbridled forces, and from it have come some of the most eloquent portrayals of landscape ever penned, among them the following:

The Sahara, though frequently tawny in spots, runs through the whole gamut of colors. In the early morning it is a dirty bluish gray, of much the same tone as the refuse from a soda-ash manufactory; but as the sun rises it becomes a dazzling white, like drifted snow, so glaring that the eyes must be protected with tinted glasses. Under certain atmospheric conditions, however, I have seen the outcropping rocks of the hammada become as red as the walls of the Grand Canyon. But the desert assumes its loveliest tints with the approach of nightfall, when it gradually changes from white to vivid orange, to blue, to amethyst, to deepest purple. Then when the stars come out, it changes to gray again, an indescribably soft and misty gray, like smoky chiffon over silver tissue.[1]

With minor changes as to detail, this description so vividly given for the Sahara would fit any of the other deserts—the Arabian, the Thar, the great desert of Australia, the Namib, or the Atacama. The centers of these areas are mostly barren wastes, but from those centers outward there is a gradual change from bareness of vegetation, through scattered bush and shrub, to the more richly clothed grass and tree steppes. The heart of the desert, the true wasteland, is without permanent human occupance; it is a place to be traversed if necessary, but not lived in.

[1] Alexander E. Powell, *In Barbary*, New York: Appleton-Century-Crofts, Inc., 1926.

Native vegetation. The native plants are highly specialized to conserve and utilize moisture when it is available. This specialization is observable in the root systems, in the leaf and stem structure, and in the distribution of the plants. Most perennials have roots that may penetrate scores of feet downward in the search for water. Other root systems are shallow and intricate, and when the occasional dashing rains come, this intricate network of roots springs into action and literally drinks up the water before it has time to escape by evaporation into the atmosphere. Plants such as the cacti have developed thick roots and fleshy stems and leaves by means of which they conserve the needed moisture. A large percentage of the plants are equipped with leaves and stems which have glossy skins, sometimes underlain with corklike zones; such structures retard evaporation and cause a little water to last a long time in supporting the circulation of the plant. Furthermore, plants grow far apart, thus allowing more room for the roots of each. These types of vegetation furnish sustenance for pasturage.

Soils. If there are any soils, they are usually thin and gray. They rarely develop distinct profiles such as are characteristic of soils in humid areas, but are rich in soluble minerals because of little or no leaching. In the extensive, flat depressions so common to desert areas (salt flats or *sebkhas*), where water gathers after showers, the soils may be so heavily impregnated with mineral salts that they are unproductive even under irrigation (alkali soils).

In many of the drier parts of the deserts there is no soil, properly speaking, only bedrock or mantle rock. In deserts the actual weathering is mainly physical, because of the lack of water, chemical weathering is slow, notwithstanding the high temperatures which prevail in the tropical latitudes. As a result of deflation processes, sands, rather than clays and silts, are dominant, the finer materials having been carried by winds to surrounding, more humid areas. Clay material is washed together into the salt flats (sebkhas) mentioned above. Since the land surface lacks the protection of a continuous vegetative cover, wind erosion is marked; desert "pavements," consisting of areas covered by rock fragments from which the finer materials have been swept away by wind action, are well-known features of deserts. Elsewhere areas of shifting dunes or the areas of more permanent dunes called *erg* make up the land. In the latter the landscape often takes on a billowy appearance. Frequently, however, the dunes are arranged in long rows that may run for hundreds of miles, with intervening narrow valleys. To cross such areas in any direction other than one parallel to the alignment of the dunes is extraordinarily fatiguing. The common conception of a desert like the Sahara as a sea of sand is erroneous. For example, only one fifth of what could be called until recently the "French" Sahara consists of sand-dune areas.

Utilization of tropical steppe and desert lands. Tropical steppe and desert cannot be separated by a sharp line: they shade into one another almost imperceptibly. Toward the desert, vegetation becomes poorer and sparser until it practically disappears in such out-and-out desert areas as the so-called Tanezrouft, west of the Ahaggar Mountains in the central Sahara.

Similarly, it is impossible to sharply separate land uses in the two areas. Where during part of the year soil moisture in the steppe lands is sufficient, crops such as sorghum, millet, or barley can be grown, providing grain mostly for food (Fig. 109). In irrigated areas, such as along the upper Niger river in the neighborhood of Ségou, even rice and cotton can be produced. On the whole, however, as in the adjacent desert areas, most of the land is used for grazing purposes. The types of animals kept depend upon the quantity and quality of available natural feeds, from cattle (hump-backed or not hump-backed) and horses on the better lands, to sheep, goats, and camels on the leaner lands. The flocks which constitute the productive basis of wealth on the driest lands consist of sheep and goats. In most desert areas cattle do not prosper; the herbage is neither plentiful nor succulent enough for their needs. Sheep and goats have developed resistance to scarcity of

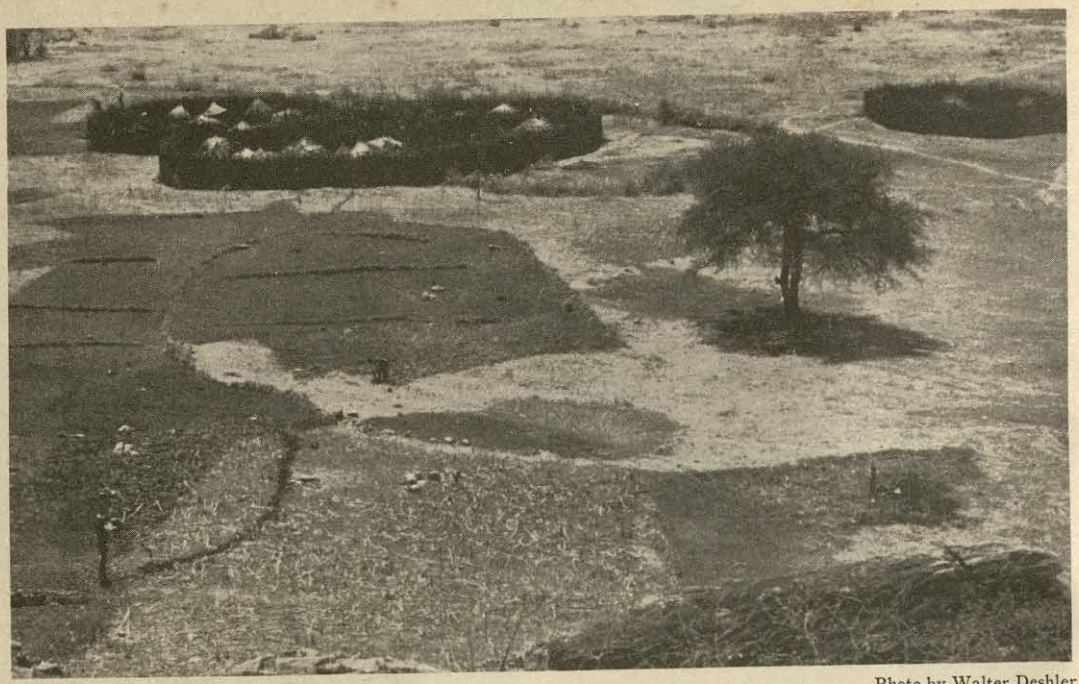


Photo by Walter Deshler

Fig. 109. Shifting agriculture in semiarid tropical Africa (Uganda). The field in the foreground is being hoed before planting sorghum. The walled enclosure in the background is a combination homestead and cattle corral. This is a marginal area for tillage agriculture, as indicated by crop yields ranging from nothing to 7 bushels per acre.

water and tolerance for rough feeds far beyond that of cattle; they therefore accompany man farther into the lands of hardship and furnish sustenance where without them he could not survive.

Most land that is good for nothing else will, without man's intervention, grow some type of plant that some kind of animal will eat. Since that is true at the edge of the desert, the herdsman is at home there. On the somewhat better among the poorest lands he raises sheep; on the leanest lands, he must rely on animals that will utilize feeds so coarse that the sheep spurn them. There, the goat is the chosen one upon which man must depend. We laugh at the goat for his great and varied dietary habits, but these are prized abilities in the land of little rain and scant, coarse herbage.

The animal industries consist of production of animals for: (1) power and transport—camels, horses, and donkeys; and (2) food, clothing, and shelter—sheep and goats. At the edge of the desert, donkeys outnumber horses, and goats outnumber sheep. The camel has been the means of long-distance transport; the donkey, the "small car" for short hauls; the horse has always been the symbol of aristocracy, the "Rolls Royce" of the desert.

As one proceeds from the better sections of the steppe lands toward the desert, sedentary agriculture, except in oases, becomes more and more difficult, and people and their flocks have to move with the seasons toward or away from the desert. This zone of mobility includes not only large portions of the desert, but also much of the steppe belt, the pastures of which seasonally attract the desert dwellers. Fig. 110 shows a portion of the Sudan in Africa and the seasonal movements of tribes in the area. These, then, are areas where nomadic life is still important, although in places, as in southern Algeria, great efforts have been made to accustom some nomadic tribes to a more sedentary existence near newly drilled wells.

In the desert, crop farming can be carried on in small areas subject to periodic,

local flooding. This is known as *temporary flood-water irrigation* and is practiced in Africa, in Arabia, and even by the Indians of the American Southwest. A more permanent type of crop farming can be carried on in oases.

Local oases occur where there are wells or springs or where shallow underground waters of the wadis sustain plant growth (Fig. 111). In the Sahara the smaller oases appear from the air as green patches in an otherwise tawny landscape. Motor tracks and camel paths converge upon them. In some sandy lowlands the ground water is so near the surface that it may be made available for plants if a few feet of the dry sand are removed. In such a manner true sunken gardens are produced, and the principal work of cultivation is to keep the inblowing sands from covering and smothering the vegetation, as in the Souf region of southern Algeria, east of Touggourt.

Most oases are very small in extent, and the acreage in crops is severely limited by the amount of water available. Common crops are dates, wheat, barley, sorghum, millet and corn, vegetables, and fruits such as apricots and figs. There are some large oases. Strictly speaking, the valley and delta of the Nile river in Egypt constitute a very large oasis, and there are other quite extensive irrigated areas in Mesopotamia, the lowland of the Euphrates and Tigris rivers in modern Iraq.

Date production. The principal commercial crop of the desert is the date. The date palm is perhaps the oldest known cultivated fruit tree in the world. The early records of the Sumerian and Babylonian peoples in the Tigris and Euphrates valleys show that it was widely tended by farmers several thousand years before Christ. The technical name of the date palm is *Phoenix dactylifera*. Its optimum habitat is in warm lands where there is practically no rain, but where irrigation is possible or ground water available. It is a tree of the oasis, not of the waterless desert. It is probable that in Assyrian times some wise observer discovered the art of artificially pollenizing the date palm and thus achieved one of the earliest advances in scientific agriculture, an achievement which has continued to be of great importance ever since.

The Arabs introduced the palm and the art of its cultivation into Spain. The Spanish

Figure 110.

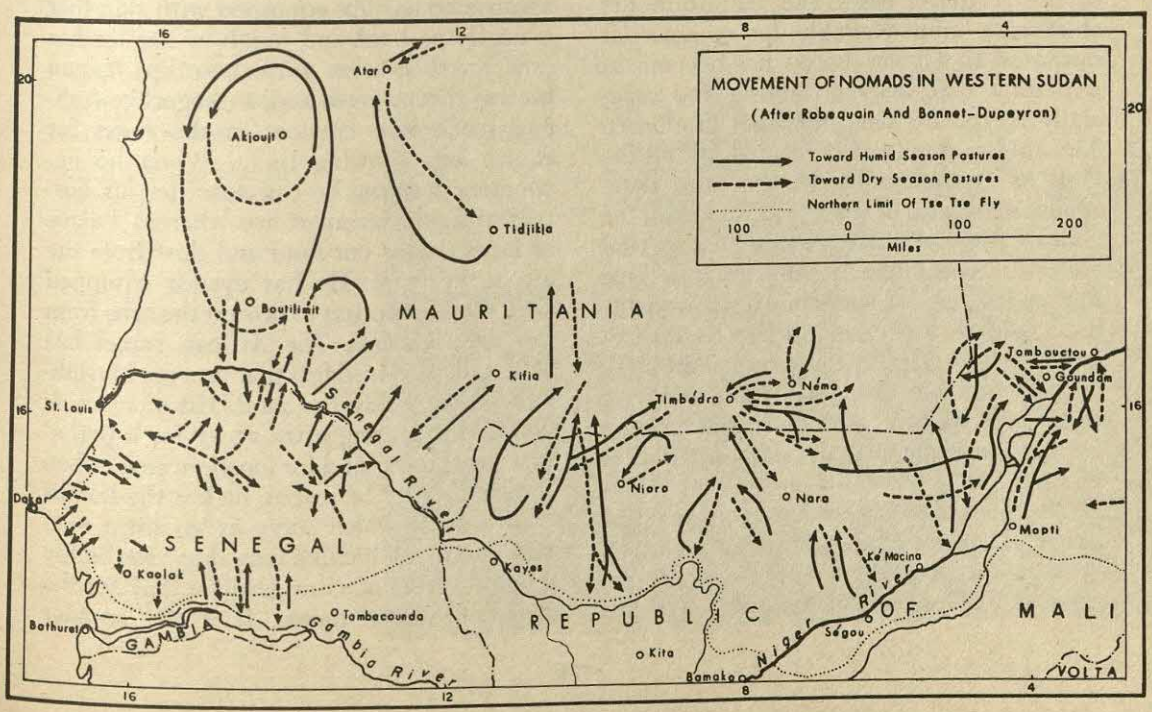




Fig. 111. Wadi bed filled with water at the oasis of Colomb-Béchar, in the northern Sahara desert. A date palm grove in the background.

Courtesy Government of Algeria

missionaries brought the seed with them to Mexico and California and under favorable conditions produced dates successfully, thus initiating what has developed into a sizable modern industry in the Coachella Valley of southern California.

The centers of large-scale production of dates have, however, remained in the East. In Africa dates make up the principal crop of the scattered oases and constitute the chief cash crop available for commercial purposes. In Algeria, Biskra has become an important date market. Tunisia and especially Egypt are also important producers. The lands around the Persian Gulf and the Gulf of Oman constitute the major date-producing center of the world. In Oman the fruit is raised by irrigation in the coastal valleys in such abundance that it has become the leading export commodity. In Iraq the date gardens are found in the fertile irrigated lower Tigris-Euphrates plain. The date is valuable as a local food and as a cash crop. Basra is the chief export center for the Mesopotamian and adjacent Iranian areas.

The date has long been recognized as essential in the scheme of desert agriculture. It is claimed that Mohammed was careful to teach this lesson to his followers, and that at one time he said to them: "Be good to your Aunt the Palm, for she is made of the same clay that you are." They have taken care ever since, even in times of war (no matter how severe the conflict), so that the date palm would not be harmed.

The camel. Among domestic animals the camel is the classic example of adaptation to the desert. He can eat coarse feed because he has lips equipped with skin that is nearly as hard and tough as the leather used for shoe soles; with those lips he can browse thorny bush and, in fingerlike fashion, reach into crevices in the rocks for choice bits growing there. When he encounters a storm, he can constrict his nostrils to small-size apertures wherein a sieve of hairs strains out sand and dust from the air he breathes. He has eyelids equipped with double shutters to protect the orbs from the driven sands. The African camel has soft, wide-surfaced feet that prevent his sinking too deep into the sand. His stomach is adapted to storing extra water for a period of several days. And for long journeys, when foodstuffs may be scarce, he has the humps on his back which serve as an extra feed supply upon which he may draw for bodily energy—a sort of extra gasoline tank for the animated desert motor. Is it any wonder

that the camel has, through the ages, been man's chief reliance for transport over arid and semiarid lands? (See Fig. 112.)

Today, however, the camel is in the process of being displaced by the airplane, the truck, and the automobile. For example, it is possible today to buy, during the winter months, a bus ticket in Colomb-Béchar in southern Algeria and in five and a half days to arrive on the other side of the Sahara Desert, in Gao, a city located east of Timbuktu. Other bus lines connect such oases as Ouargla, El-Goléa, In-Salah, and Ghat. There are also several airlines which regularly cross the Sahara.

Desert mode of life. Over centuries man in much of these dry lands has of necessity been a nomad. He has had no choice in the matter. Except in oases and the more favored portions of the steppe lands, tillage agriculture is too hazardous an enterprise to build upon it a sedentary mode of life. The main economic basis of life has had to be grazing—the utilization of the comparatively sparse natural vegetation. As the rainy season is short and, in the desert areas not only very short but also unreliable, mobility of man and beast has always been a prime requisite. Life at the edge of the *oekumene* has been hard, but it has bred a sometimes fierce independence. The nomad is proud of his way of life and is often scornful of the soft life of the sedentary oasis dweller or of the farmers in the better-watered areas.

Life is tribal and of the large, patriarchal family. Differentiation of labor has always been sharp: men are the herdsmen and the fighters, women carry on the home industries and generally do most of the work if any tillage is possible. The flocks provide wool and hides, the chief basis of the household arts. Tannin-producing plants make possible such skilled work as the production of Moroccan leather. The fine and strong fleece of sheep and goats yields the raw material for rugs and shawls. The women, working patiently with hand spindles and looms, weave rugs noted for their durability and artistic beauty. Such rugs are useful objects in the domestic life of the nomads: they serve as ground covering in the tents and are used on couches and beds. They can readily be folded or rolled, a desirable quality for people who are always on the move. Of all the different types of rugs made in these dry regions the Persian types —made in Iraq, Iran, and Baluchistan—have acquired world fame, and under the name of "Oriental" are exported in considerable quantities to the West. Of course, many such rugs nowadays are not made by nomad women living in tents, but in regular rug-weaving establishments.



Fig. 112. Desert nomads on the move in Mauretania, western Sahara desert.

Courtesy Institut Francais d'Afrique Noire, Dakar. Photo by G. Labitte

For centuries the tendency of the nomadic tribes has been to raid the settlements in the adjacent richer lands, where are produced many of the things nomads lack. When government is strong, and raiding is difficult or even impossible, trade has to be relied upon, and nomad and farmer can exchange products to the advantage of both at markets in settlements at the edge of the drier lands. Such market places have always flourished best along major trade routes, and the towns which developed as a result also became outfitting centers for the caravan trade. Such towns have always been picturesque in the variety of people and products attracted to them. Their market places exhibit dates and grains, squares of salt from salt pans of the desert, sugar in loaves, tea, prayer rugs, saddle rugs and tent rugs, hides and skins, leatherware, cotton cloth, onions, melons, and a multitude of other products, local and imported. And between the stalls may walk a colorful crowd of farmers, traders, and nomads.

But the dry lands are also changing. The great caravans have disappeared: the truck is taking jobs away from the camel, and the number of camels is declining. Thus herds have tended to grow smaller, and nomadic movements in a number of areas have become more limited. The tribes stay longer in the neighborhood of the oases, and, finally, only the herds and the herdsmen move, and houses take the place of tents. Modern methods of drilling deep wells, as in southern Algeria and Tripolitania, have added a bit to the small amount of cultivated land and have made it possible for some tribes to become sedentary. However, unemployment and underemployment have also resulted. To this have come the disturbing effects of the finding and exploitation of petroleum in Arabia and in the Sahara. True, this has provided work for many nomads and oasis dwellers, but not by any means for all. And, besides, what can be done when the oil gives out?

Certainly, in the driest areas, the deserts, it would be impossible to make sedentary agriculturalists out of all the nomads. Even with modern well-drilling methods there is not enough nonsalty water available. There is a growing body of evidence, for example, that in northern Africa about 8 to 10,000 years ago much of the Sahara was not as arid, perhaps at most semiarid. It is quite possible that at least part of the present ground water dates back to this period and to more rainy Pleistocene, so-called Pluvial Periods. If this is so, then part of the water withdrawn by deep wells would not now be replaced by natural means. Also, in all of the steppe areas the water problem is crucial. There are areas where more water can be made available and where there is land that has the right topography for irrigation purposes, but the sum total of these areas is small. Thus grazing will, or should, always remain important. However, more intensive development of the semiarid tropical lands must await the time when the increased population of the world will have utilized the humid savannas and when man will have to be satisfied with the less desirable areas. Then choice will have to be made between the dense jungle and the rain forest of the equatorial belt on the one hand and the semiarid steppes on the other. From the standpoint of the middle-latitude demands, the chances favor the warm wet lands because their products cannot be duplicated in the cooler lands, whereas the animal products of the warm semiarid countries do not differ greatly from those of cooler climes. For example, bananas, coconuts, and cacao, products of the warm humid lands, have no competitors in the northern markets; on the other hand, products of the warm dry lands, such as tropical goats, sheep, and cattle, have no such monopoly, but must meet the direct competition of their kind produced in cooler climates and generally under more favorable conditions as to environment and markets.

Where people cannot depend on remaining in one place, individual property values cannot center upon land, so size of flocks is usually the criterion of wealth. Real estate, as such, does not and cannot permanently belong to any individual, but is generally held to be the property of the tribe. Thus property rights are maintained only by continual vigilance and constant mobilization for defense or attack. The land belongs, for

the time being, to the tribe that holds it and, if necessary, fights successfully to keep it. The occupations of men—herding, hunting, fighting—are dangerous, and hence mortality has always been high. Thus there has been a surplus of women in a social group which had no opportunity of employment as stenographer, clerk, nurse, teacher, social secretary, or any of the other numerous openings that are available for women in the more advanced civilized communities. In order to survive, women have had to be attached to households, resulting in polygamy, an adaptation to the conditions under which existence must be maintained.

On the whole, the desert's edge has always been a taskmaster with sharp requirements. It has produced strong, fearless, and virile people. These are the characteristics most conducive to success under the conditions which prevail where desert brown and grass green intertwine, because there man must be able to move quickly, to run and to ride; in this contest, lean men survive because fat men can neither run nor fight.

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11

The Regions of Mediterranean Climate

unique characteristics and typical products

POLEWARD FROM the tropical climates are areas where most of the months are warm to mild, but where there is a short winter season, cool and with occasional frosts. The climate of these areas is called *subtropical.* In essence it is transitional; in the Northern Hemisphere during the summer months the characteristics of the weather are influenced by pressure conditions farther south, while during the winter months they are affected by conditions to the northwest and north. In the corresponding belt in the Southern Hemisphere a similar alternation of influences occurs. In the subtropical regions temperatures show a marked seasonal rhythm, and hence we find the terms *winter* and *summer* in common use.

In this discussion subtropical climates are defined on the basis of the average temperature of the coldest month—which is more than 43°F. (6°C.) but less than 65°F. (18°C.), with possibility of occurrence of frost. Whereas the colder parts of these areas may have frost-danger periods up to four months in length, the warmer parts in some years may have no frosts at all. In other words, in the different parts of the subtropical belt the annual frost-free period, often called the growing season, varies in length from nearly a full year to slightly more than eight months.

There are pronounced differences between the subtropical climates of the eastern and western parts of the continents. In winter the moving air masses of the belt of prevailing westerlies bring rather stable oceanic temperatures to west coasts and variable continental temperatures to east coasts. Thus Los Angeles, California, has a difference of only 16 degrees between the mean temperatures of the coldest and warmest months (55°F. in January, 71°F. in August), while Charleston, South Carolina, has a range of 31 degrees (50°F in January, 81°F. in July). Similarly, Cadiz in southern Spain has a range of 24 degrees (76°F. in the warmest month, 52°F. in the coldest month), while Shanghai, China, shows a range of 42 degrees (80°F. in the warmest month, and 38°F. in the coldest month), even though it is located about 350 miles farther south. As a result of oceanic versus

continental influences, the mild winters of the west coast type extend farther poleward than do those of the east coast type. It should be mentioned, however, that in the Mediterranean region, a west coast area, because of its great extent temperature ranges increase eastward, away from the Atlantic. While that at Cadiz is 24, the range at Tunis is 30 and at Athens 34 degrees.

Rainfall contrasts between west and east coasts are even more striking. The former have a rainless summer, while the latter have rainfall at all seasons or, in the case of southern China, a pronounced summer monsoon maximum of rainfall. Los Angeles has a period of about five months, from early May to late September, with no rainfall whatsoever in most years. The driest month at Charleston, South Carolina, has 1.8 inches of rainfall on the average. The storms from the Pacific pass to the north of California in summer, and, particularly during June, July, and August, fair weather prevails, related to a well-developed high-pressure area offshore. This high-pressure area may be considered a segment of the great high-pressure belt north of the equator that is the source of the northeast trade-wind system. The trade winds, blowing from higher to lower latitudes, or from cooler to warmer areas, generally cause dry conditions. However, in southeastern United States, an area located in the latitude of the summer trade-wind system, the effects of low-pressure areas passing farther north are felt even during the summer months. Besides, part of the northeast trade winds of the west Atlantic are deflected northwestward, toward the coasts of southeastern United States. This deflection, a mild monsoonal effect caused by prevailing low pressures in interior North America, brings masses of marine air to the land and results in considerable summer precipitation and even some cooling.

In the Mediterranean region, which is more typical for the west coast phase than California, the roots of the trade-wind system prevail in the summertime, with rather constant northwest, north, and northeast winds, while during the winter months the weather is governed by lows that develop locally, frequently over portions of the Mediterranean Sea, and by air masses that are part of the prevailing westerlies or northern cyclonic circulation, and which enter the Mediterranean from the west via southern France and southern Spain. The summer winds cause dry weather, except where they hit mountain ranges, while the winter circulation causes precipitation. The west coast type of climate is called *dry subtropical* or *Mediterranean* climate, while the eastern type is called *humid subtropical.*

DISTRIBUTION AND CHARACTERISTICS OF THE MEDITERRANEAN CLIMATE

The Mediterranean type of climate attains its most extensive development along the margins of the Mediterranean Sea, from southern Portugal and Spain to Palestine—a west-east stretch of over 2,000 miles (Fig. 113). As mentioned, part of California has such a climate. Other regions of Mediterranean climate are located in Chile, South Africa, and southern Australia. In California the area with Mediterranean climate embraces the southern coastal region and the major part of the Valley of California. In Chile this climate is typical for the central part of the country between the 32nd and 37th parallels, a strip of land about 300 miles long and 75 miles wide. The Andean slopes to the east are of little agricultural significance. Also, the Coast Range, with an average width of 20 to 25 miles is of limited use. Thus the economically important part of the area is restricted to the Central Valley. Even here spurs of the Andes and of the Coast Range further limit the amount of level land suitable for agriculture. Nevertheless, this region, due to early occupation and irrigation, is the most important part of Chile. In Africa the region with Mediterranean climate is a small area near Cape Town; in Australia it embraces the coastal regions near Perth, Western Australia, and near Adelaide and Port Augusta, South Australia, as well as a portion of Victoria. (See World Map of Climatic Regions.)

Rainfall and temperature. The amount of annual rainfall differs considerably from region to region, but for the most part it is

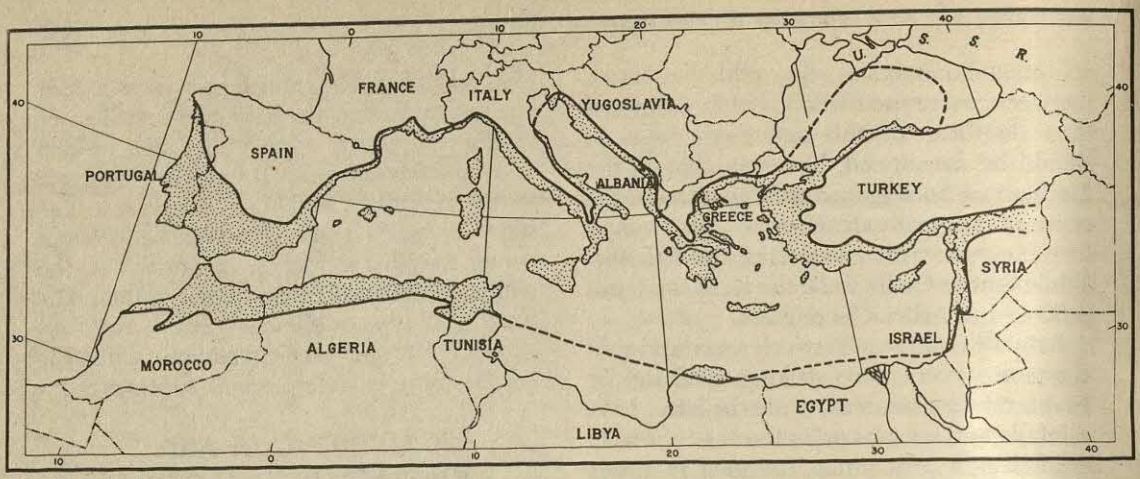
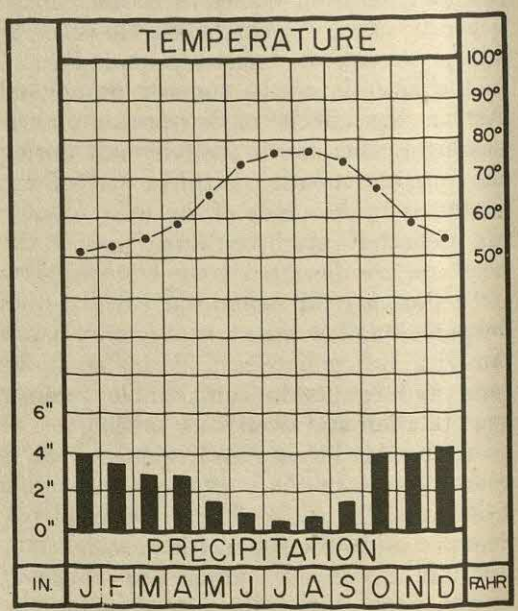


Fig. 113. The areas with Mediterranean climate (No. 6) around the Mediterranean Sea. Note that this type of climate is not found in the highland areas of Turkey, the Balkan countries, Italy, and part of the Spanish highlands. East of Tunisia steppe and desert reach to the coast.

about 25 inches or less. On the whole, rainfall decreases from the poleward margins which adjoin more humid lands toward the warm deserts of lower latitudes. Thus while San Francisco, California, has 22 inches of precipitation, San Diego, located 350 miles farther south, has only 10 inches per year; Jerusalem in Israel has 10 inches less rain than Rome, Italy, 1,000 miles farther north. The rainfall, therefore, approaches humid conditions at one margin and arid conditions at the other. The distinctive feature common to all areas of Mediterranean climate is the rainy winter and dry summer. Palermo, on the island of Sicily, southern Italy, has a total annual rainfall which is not particularly large and a pronounced dry season in June, July, and August (Fig. 114).

In temperatures, too, differences are pronounced within the areas of Mediterranean climate. Poleward and inland from the coasts, frosts are more frequent and severe than equatorward and seaward. Differences in altitude also are important; as elevation increases, average temperatures become lower. In the Mediterranean area many of the mountains are so high and temperatures so reduced as a result, that these regions cannot be considered to have a Mediterranean climate. Thus, much of the Apennines (particularly the high Abruzzi), the Sierra Nevada, the Dalmatian Mountains, the Pindus chains of Albania and Greece, and the Atlas Mountains of North Africa have climatic conditions which differ greatly from those in the adjacent lowlands. Natural vegetation, soils, and crops differ accordingly.

Fig. 114. Dry subtropical climate. Average temperature and precipitation, Palermo, Sicily. Altitude 213 feet, total precipitation 30 inches.



Mountain barriers often afford protection from cold winds, thus accentuating the Mediterranean character of the areas at their foot. The Alps and Caucasus, for example, shut out fairly effectively the cold air masses that in winter often lie over southeastern and central Europe. Just south of the mountains are many sheltered spots where winters are mild and sunny and where those in search of health or pleasure may escape the damp, raw, dreary winters of the north. The French and Italian Rivieras, the Italian lake region, and the Dalmatian coast, like southern California, are sheltered spots of winter tourism.

Temperatures likewise reflect the fact that the oceans have more stable temperatures than the continents. Thus at Eureka, on the California coast, the warmest month is only 9 degrees warmer than the coldest (47°F. in January, and 56°F. in July), while at Redding, California, 100 miles inland, the difference is 37 degrees (45°F. in January, 82°F. in July). However, with all these local differences, the areas concerned have the common trait of a short cool season and long warm season, and in most places a frost-free period lasting more than nine months.

Winds. During the winter the trade-wind system moves equatorward, and areas of low barometric pressure, associated with the cyclonic circulation of the middle, or intermediate, latitudes, begin to enter the regions of Mediterranean climate. In California the pressure conditions of the winter season bring masses of marine air from over the Pacific Ocean. Southerly winds, often accompanied by rain, predominate as such an air mass approaches the coast. As the front of the mass passes, the wind may be gusty and variable, followed by a northerly wind usually accompanied by clear, cooler weather. This sequence of winds, often including a period of calm, may have innumerable variations.

In the Mediterranean region barometric pressure during the winter season is very irregular. Local low-pressure areas tend to develop over each of the several main subdivisions of the Mediterranean Sea, while over the adjacent land masses barometric pressure tends to be above the average. From time to time cyclonic lows enter the Mediterranean region from the side of the Atlantic Ocean. All this results in changeable winds and periods of rain, alternating with dry, sunny weather. On the whole, the pressure differences resulting from the contrast between the comparatively warm waters of the sea and the various cool to cold adjacent land masses, are primarily responsible for the typical winter weather and *not* the air masses from the Atlantic that from time to time invade the area. This circumstance is also largely responsible for the fact that the true Mediterranean climate is limited to the coastal areas.

Sudden influxes of cold air in the winter half of the year are notorious features of Mediterranean areas. In southern France a cold wind known as the *mistral* occasionally sweeps violently southward to the Mediterranean coast through the natural funnel of the lower Rhône Valley. This wind occurs when there is a high pressure to the north and a deep local depression over the Mediterranean immediately to the south. Cold air from the snow-covered Alps and the Central Plateau of France starts streaming southward, funneled by the Rhône Valley. Even though it should, as a descending wind, gradually get warmer, by the time it reaches the Mediterranean it is still quite cold. A similar wind, the *bora*, occurs along the Adriatic coast during periods of high pressure to the northeast and north and pronounced low pressure over the Adriatic. In the days when navigation depended upon small vessels using sails, the mistral and bora were dreaded by sailors, as they could easily sink the ships.

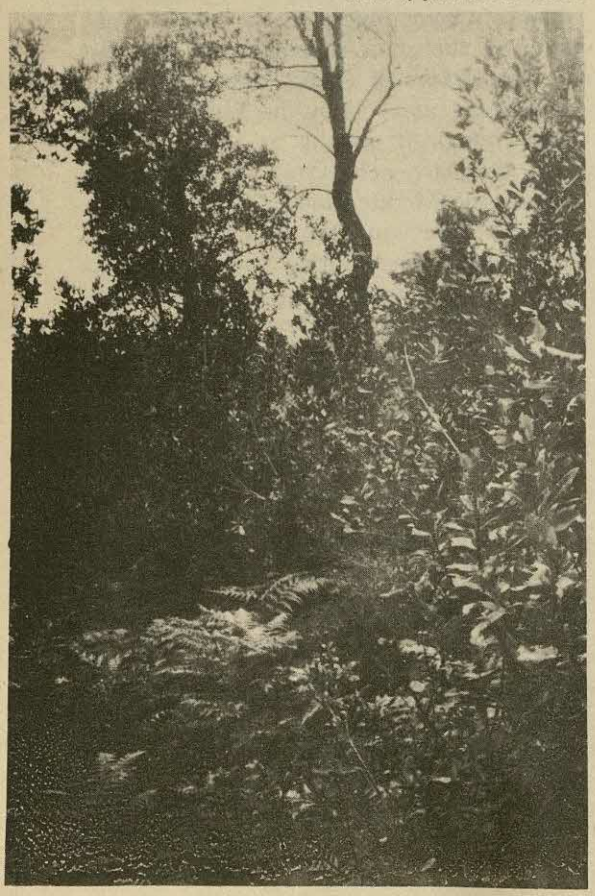
Hot, dry winds sometimes blow into these areas from the deserts that lie equatorward. Such winds may carry parching desert air and clouds of dust from the Sahara Desert northward across the Mediterranean to southern Europe. In Sicily and southern Italy this wind is called the *sirocco;* in Spain, the *leveche;* in French North Africa, the *sirocco;* in Egypt and farther east the *simoon;* in southern California, the *Santa Ana.* The approach of the sirocco is heralded by a haze over the southern horizon,

the haze gradually overspreads the sky, and the storm breaks with a burst of wind, dust, and sand, lashing the sea to fury. The relative humidity may drop to as low as 10 per cent, and the dryness may ruin the crops of olives, vines, and other fruits if the storm comes during blossom time. The sirocco and Santa Ana may last a few hours or for two or three days.

The renowned colorful sunsets of Mediterranean areas are the result of fine dust blown high into the air during the long dry summers. The coloring is most striking where the dust is very fine, as in the volcanic areas of Italy. The Mediterranean Sea serves as a great mirror to emphasize the sunset colors. Such sunsets are a distinct economic asset to tourist agencies.

Fig. 115. It is difficult to take pictures of the dense mediterranean scrub forests referred to as maquis in France, and macchia in Italy, without getting one's clothes torn by some of the thorny plants in the mixture. No wonder that during World War II the maquis was an excellent place for finding shelter and from which to carry on guerrilla activities. This photo was taken in Southern France.

Courtesy Jean-Claude Thomas



Native vegetation. The totality of climatic conditions is reflected in the native plant cover of an area. The characteristics of the Mediterranean climate that most profoundly affect the vegetation are as follows: (1) rain falls abundantly in the winter half of the year, especially on exposed slope lands and in the parts of the subtropical belt farthest from the equator; (2) summer is a period of complete or partial drought; (3) the winters are mild, and the summers warm to hot.

The most obvious effect of these climatic conditions is to produce a carpet of brilliant green in winter and of subdued brown to yellow in summer. Many trees and shrubs are evergreens which are able to grow at least during part of the winter season and the spring. During the summer months, however, they are exposed to the burning sun and therefore have developed protective devices against extreme loss of moisture. As a result, most evergreens have hard leathery leaves, often thickly set with fine hairs to further restrict evaporation. Many deciduous perennials have only inconspicuous leaves, green stems, and long thorns that take over the leaf function (Fig. 115). Annuals can exist only during the rainy season. Grasses and low-flowering plants begin to grow from bulbs or seeds after the first rains in the fall; they bloom in early spring, and wither with the advent of the dry, hot summer.

Much of the original forest vegetation of the Mediterranean region was cleared long ago for agricultural purposes or has been reduced to brush by the goat and by man's centuries-long quest for firewood and lumber. Still, forests survive in many sections, sometimes even in the lower regions. Examples are the cork-oak stands of the western Mediterranean or the woods of Aleppo pine. In general, however, forest trees do better on the higher slopes, and important stands of timber may be found on slopes exposed to moisture-bearing winds. The timbers used by the builders of Solomon's Temple

and for the construction of boats by the Mediterranean seamen were obtained from such localities. As has been mentioned before, however, many of these higher areas are really areas of mountain climates, located above the typical Mediterranean regions. As most people live in the lowlands, where timber is not readily obtainable, stone and sun-dried brick have long been the common building materials, particularly in the Mediterranean countries of Europe. In the United States the regions of Mediterranean climate are smaller, and modern transportation facilities make lumber so easily available that wood is generally used for construction purposes.

Much more characteristic and far more widely distributed than the high forest are thickets or scrub forests, often thorny and consisting of scattered trees and dense masses of scrubs with much undergrowth. This type of vegetation, with regional modifications as to species, is common to all areas of Mediterranean climate and frequently occupies areas where high forest once existed. The French name *maquis* has been accepted to designate it. In California it is called *chaparral.* The *maquis* is the source of bundles of sticks peddled as firewood in the streets of Mediterranean cities and villages, and of *manzanita* firewood widely used in California. Charcoal has long been made out of some of the larger stems and branches.

There is a lower and even more scraggly type of vegetation than the *maquis.* Inasmuch as the soil may be bare and unprotected by the end of summer, heavy winter rains may remove much of the finer material from steep slopes. These slope lands with their stony soils are quite extensive and, especially in the Mediterranean countries, support a sparse vegetation made up of small, drought-resistant bush. The Germans call these forms "half shrubs," an aptly descriptive term because they are halfway between herb and shrub in size. The commonly accepted term is *garigue,* the term used for this vegetation in southern France.

On might at first think that the *garigue* and the *maquis* could have little value. However, sheep and goats can thrive on coarse forms of vegetation. Sheep do quite well where the *garigue* and *maquis* are fairly open; where the vegetation is more tangled and coarse, goats are able to find nourishing feed. Through its fodder value, this thorny, inhospitable vegetation contributes directly to the kid slippers and gloves for the ladies of Paris, London, and New York. Furthermore, the abundant blossoms of these plants are harvested by bees, a fact which is significant now but which was even more so in earlier times, when honey was the only sweetening available.

A striking element of the vegetation is the dwarf palm, which is characteristic of the Mediterranean countries, especially those of northern Africa, and which has been widely introduced elsewhere.

Soils. Because of the low rainfall in these climates, leaching is slight, and the soils in most cases are pedocalic. The prevailing high temperatures are conducive to weathering, and therefore the soils of the lowlands are well supplied with the products of rock decay—clay and soluble mineral salts. However, humus is not as a rule abundant, a condition directly attributable to the sparse native vegetation and a flora consisting of trees and shrubs rather than grass. In general, the soils have friable structure, sandy to gravelly texture, and brown or reddish-brown colors.

Topography is an important factor in soil development in many of the areas of Mediterranean climate, particularly in the regions characterized by steep mountain or plateau slopes descending abruptly to valleys and to the sea, and where floodplains and coastal plains are relatively narrow. The topographic conditions lead to eroded, stony soils on the slope lands and soils of depositional origin on the low plains. In Mediterranean lands the contrast between plains and hilly lands often is sharp.

The lowland soils are productive. They represent an accumulation of the fine particles which have been washed down from the slope lands and deposited without much loss of soluble mineral content, either along the stream valleys or as coastal or piedmont plains. There the native vegetation flourished more abundantly than on the higher

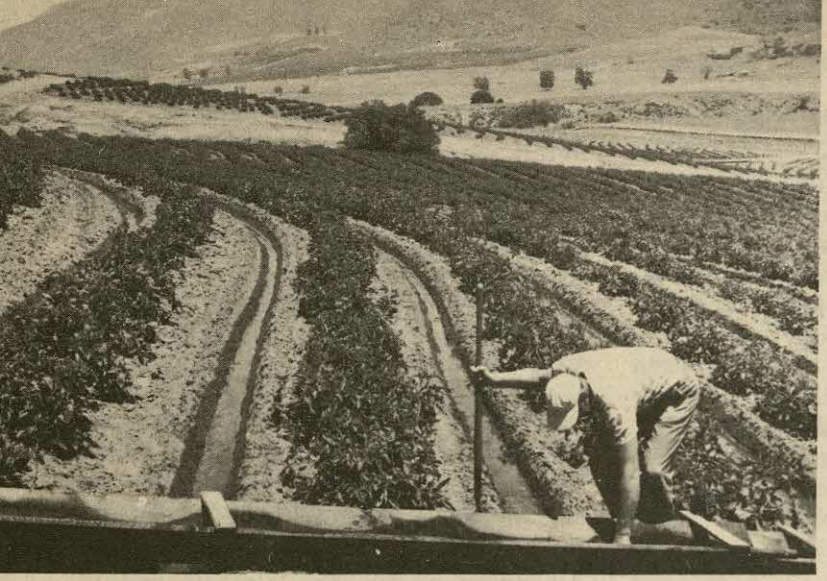


Fig. 116. Irrigated agriculture is typical for parts of areas with Mediterranean climate, so as to overcome summer drought. It is generally practiced in plains areas, but also on lower hill slopes. These are contour-planted early tomatoes in the San Diego area, California.

Courtesy U.S. Department of Agriculture

and drier slopes, and the decaying organic matter served to further enrich these immature lowland soils. Water is the great need. Where this is supplied, as in southern California or in the irrigated valleys of eastern Spain, southern Italy, Algeria or other Mediterranean lands, abundant harvests result (Fig. 116).

The soils of the slope lands, on the other hand, are generally thin and poor. This is particularly true where tillage has long been practiced. In some parts of Greece and Italy the soils on steep slopes are protected from erosion by intricate systems of terraces. Thus productivity has been maintained, but only through the cumulative labor of many generations of farmers. On the whole, the slope lands with their skeletal soils and their scanty vegetation are best adapted for nonirrigated tree crops or for use as grazing lands. In the most favored locations this pasturage will support cattle; in the more rugged sections, where only coarse herbage thrives, goats are well able to maintain themselves; elsewhere, sheep raising is the most economic phase of the livestock industry.

AGRICULTURE

The distinctive aspects of the Mediterranean climatic areas—mild, wet winters and hot, dry summers—appear to pose serious limitations to the practice of agriculture. The summer, nominally the period of plant growth, is too dry for significant crop production without supplemental water, but winter and spring are the periods when vigorous crop growth is possible. This anomaly of winter rain and summer drought actually makes possible a considerable agricultural advantage. In the Northern Hemisphere the Mediterranean type lands have easy access to middle-latitude centers of high population density and high purchasing power. In these latter areas, tillage agriculture is difficult or impossible during the winter, and thus they constitute major markets for winter- and spring-grown vegetables from farther south.

The Mediterranean lands have been occupied by advanced cultures for thousands of years. Their inhabitants imaginatively solved the problem of lack of summer moisture by the development of drought-tolerant crops and by use of irrigation. The sources of the irrigation water are commonly in the mountain areas which surround or rise above lands with Mediterranean climate. Intricate local systems for regulating the distribution of irrigation waters have been in existence in the Mediterranean area of the Old World for hundreds of years.

A further general characteristic of agriculture in the Mediterranean area of the Old World is crowding of the land. Here, as valley lands became occupied, additional land suitable for tillage was created on the steep hillslopes by carving out narrow terraces. The hill terraces, often only 20 to 30

feet across, generally are not irrigated and are planted to olives with an understory of wheat or grapes. They are a colorful and distinctive part of the landscape. However, most wheat and olives are grown on nonterraced higher or hill lands.

Two quite different types of agriculture are characteristic of the Mediterranean lands: dry-land agriculture and irrigation agriculture. The areas used for these two types stand out distinctly in the landscape, and the borders between them are sharp. This is particularly noticeable when one flies over in summer: the uplands, where dry-land agriculture is practised, look brown and parched, while the irrigated areas stand out as lusciously green oases. In Spain the irrigated areas in the plains along the Mediterranean coast are referred to as *huertas* (gardens), and such they are. Agriculture is intensive. All the land that can be used is in crops, annual crops and tree crops, often mixed on the individual parcels of land. High-yielding and moisture-loving crops predominate: oranges, lemons, peaches, apricots, corn, rice, vegetables of many kinds, melons, potatoes, sweet potatoes, flowers, and alfalfa. Insofar as the annual crops are concerned, two harvests a year are common and five harvests in two years are fairly frequent. Density of rural population is among the highest in the world. The best-known *huertas* are those of Valencia and Murcia, but there are many other *huertas*. Similar irrigated areas with dense rural populations occur in other parts of the region of dry subtropical climate in Europe, northern Africa, and adjacent Asia. In the remaining regions of the world with Mediterranean climate irrigation also plays an important role, though rural population may not be as dense, nor land use as intensive as in the Spanish *huertas*. For example, irrigation agriculture is practised extensively in California, and in the Central Valley of Chile.

On the dry land tree and annual crops are also grown, but only those that can stand the summer drought, or that grow during the winter and can be harvested before the dry weather sets in. Among the former are tree and semitree crops such as olives, figs, almonds, and grapes for wine; among the latter are especially wheat and barley.

Since early Biblical times nonirrigated wheat or barley, oil and wine, and irrigated garden crops have been typical for the Mediterranean area, and in the Scriptures of Christians and Jews references to them are legion.

Grain agriculture. The winter rains and summer drought of Mediterranean climates favor crops that mature early. Small grains rather than corn are therefore characteristic of these climates. Hard winter wheat and winter barley are the foremost cereal crops, the former being a bread grain and the latter being used chiefly as a feed grain, although it is locally important for food. They are planted after the first rains of fall or winter. Certain sections of the Mediterranean lands have always been noted as important wheat producers, and in earlier times the attempts to insure wheat supplies from such areas were often the dominating motives in commercial and even in military contests. Control of the fertile valley of the Nile, and of certain sections of Greece, Italy, and Spain was sought largely because of their value as wheat lands.

Durum wheat, popularly known as macaroni wheat, is a type that does well in areas of Mediterranean climate as it is hardy and drought tolerant. Its flour is not very suitable for bread making, but it is excellent for the making of many kinds of *pasta*, such as spaghetti and macaroni. The art of making these pastes is of Italian origin but has spread to nearly all lands. The Italians have taught practically the whole European world to enjoy their favorite dish, spaghetti.

Animal industries. Since summer drought and winter rains are more conducive to bush and shrub growth than to grass, the livestock industries have centered about donkeys and mules rather than horses, and sheep rather than cows. Sheep and goats are the mainstays of the pastoral pursuits. Where forage is relatively abundant and pastures are open, sheep predominate. Since sheep are timid, defenseless creatures, the herdsman's watchful care has always been essential. Out of this has come the symbolism of the shepherd in sacred

story and song—a symbolism expressed in the religious rites of modern church worship throughout Christendom. The mild climate and somewhat limited feed supply seem to have been conducive to the development of breeds of sheep small in size but of superior quality of wool, like the renowned Spanish Merino.

Where forage is scarce, topography rugged, and the vegetation harsh and unpalatable, the sheep give way to their more active cousins, the goats. Thus, in the eastern Mediterranean lands, in northwest Africa, and in the less-favored areas elsewhere, we find the goat, man's most tolerant and persistent producer. The world's major center of production of goat skins is the area reaching from Morocco and Spain in the west to Greece, Turkey, and Iran in the east. There, where neither grass nor grain is abundant, the goat exists, furnishing food for the local population and providing the finest hides to be made into gloves and shoes in the world's fashion centers.

Another phase of the animal industries that deserves attention is poultry raising. In these areas of nearly year-round growing season and low humidity, the poultry industry has a high place. The Mediterranean breeds of chickens are noted for their hustling abilities and their agility, rather than size. The natural habitat, with its seed-bearing bush and flitting insect life, has been conducive to the development of quick-moving kinds of poultry. From these lands the Leghorns and Minorcas have sprung, small agile birds quite unlike the heavy Asiatics. The Mediterranean breeds mature early and make high scores in egg laying. These qualities have placed them in favor as food producers and are important factors in accounting for the factory-type poultry farms of California.

Special agricultural products: fruits and vegetables. The dry subtropical lands are major areas for the production of olives, figs, prunes, grapes, and citrus fruits. Olive and fig production are largely limited to areas of Mediterranean climate. Grape production is not so limited. In Europe a number of the renowned wine-producing areas, such as Bordeaux, Burgundy, Moselle, and Rhine wine districts, lie well outside the region of Mediterranean climate. Also in the United States there are a number of districts in the eastern part of the country where table and wine grapes are produced. However, heavy production of wine grapes, grapes for drying, and table grapes (the latter produced mostly under irrigation) is characteristic of areas with a Mediterranean climate. Citrus groves are a normal item of the landscape in the irrigated districts of areas with Mediterranean climate, and a large percentage of the citrus fruit that enters world trade is produced in these regions. However, citrus fruit is not limited to areas of Mediterranen climate, but is also produced successfully in areas of humid subtropical and tropical climate, such as Florida and Brazil respectively.

The lands around the Mediterranean Sea rank foremost in the production of olives, figs, currants, wine grapes, oranges, and almonds, while California holds first place in prunes, raisin grapes, and lemons. Grapes and citrus fruits are of economic importance in each of the other dry subtropical regions as well—South Africa, central Chile, and southern Australia.

Olives. The olive appears to have been native to Asia Minor, being one of the earliest trees cultivated by man. The gift of the fruit was a token of peace among the barbarians of early times, and a branch of the tree became a symbol of peace. The importance of the olive as a source of fat in the diet of the people of eastern Mediterranean lands is attested by the frequent references to it in sacred literature (Fig. 117).

The olive industry is chiefly dependent upon one species of tree, the *Olea europea* (European olive), of which there are many varieties. The tree, a tough, narrow-leaved evergreen, is noted for ease of propagation, resistance to dry conditions, heavy yield of fruit, and longevity. It does not need irrigation, and therefore in the Mediterranean region olive groves are generally found on the hillsides or in stony parts of the plains. In many districts olive trees are interplanted with grape vines or even with wheat. By the

12th to 15th year an olive grove should be in profitable production, furnishing 20 to 40 pounds of olives per tree, and it should continue so for many decades. The oil content averages 10 per cent. Olive trees more than a century old are common in the Old World, and many instances are known where the age is supposed to be 500 years or more.

The olive harvest comes at the beginning of the winter rains, in the Northern Hemisphere usually in November. High-quality olives are picked by hand and are always kept scrupulously clean. In many of the older producing sections such care is not practiced—the fruit is shaken from the trees by beating the branches with poles, and the olives are picked from the ground in more or less bruised condition. This practice lowers the quality of the oil and causes undesirable flavors to develop.

Although many olives are sold for table use, most are produced for oil, pressed from the ripe fruit. The quality of the olive oil depends more upon the care with which the fruit is handled than upon the soil or climatic conditions under which the olives are produced.

Olive oil is widely used in countries where animal fats are scarce. Where climatic conditions are unfavorable for the production of feed grains and grass, large-scale production of cattle and hogs is impossible. Where butter and lard are scarce, olive oil serves similar needs. Furthermore, summer heat and dryness tend to irritate the skin, creating a need for oily ointments such as olive oil.

It is not surprising that the olive is so important in the Mediterranean lands (Fig. 119). There the areas of dry subtropical climate are most extensive, people most numerous, and demand greatest. Spain, Italy, and Greece together produce three fourths of the world's commercial olive crop; other important producers are Portugal, Turkey, Tunisia, Algeria, and Morocco. California is the only important center of olive production in the Western Hemisphere. The quality of the output there is of the best, but the quantity is less than one half of one per cent of the world's total. Although California has much land well adapted to olive growth, profits are not normally high enough even to justify thorough picking, much less expansion. During World War II the price of olives quadrupled when imports from Europe were cut off, and the California growers picked large crops.

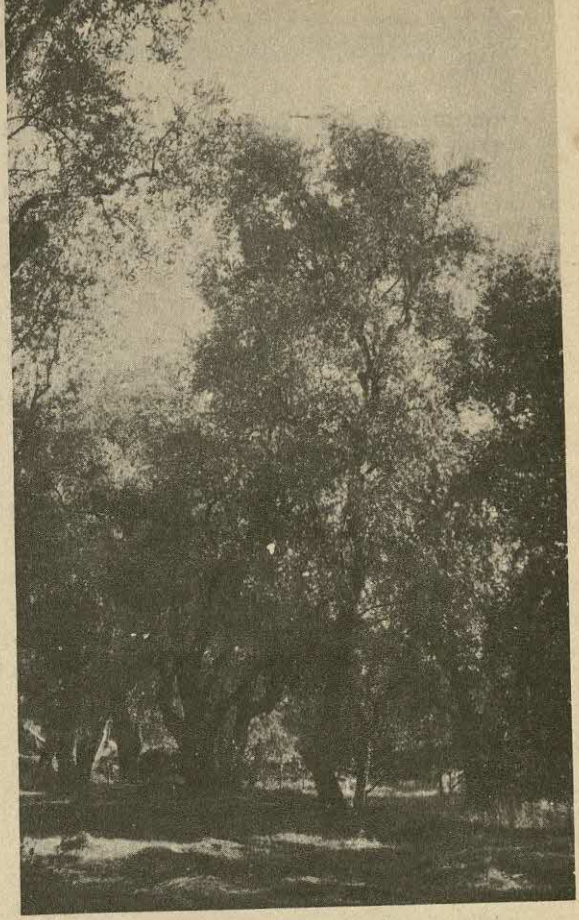


Fig. 117. An old olive grove in the area of Mediterranean climate in southern France, near Nice.

Dried fruits. Sun-drying as a means of preserving fruit has been practiced for countless ages. Nature does this in the ripening process of grains and other seeds, and man early learned to imitate Nature in the case of a number of fruits and vegetables. Until canning and refrigeration were devised, drying was the prevalent method of preserving fruits. The countries of Medi-

terranean climate have the advantage that their varieties of fruits have a high sugar content, while their dry, cloudless summers favor sun-drying. The principal fruits preserved in this way were figs, prunes, raisin grapes, and black currants, a variety of raisin grape (French—*raisins de Corinthe*) which may have originated in Greece. In spite of the tremendous development of canning and refrigeration, these still remain in high favor and are produced in quantities of great commercial importance.

FIGS. The fig tree appears to be indigenous to Asia Minor and adjacent areas, and various species are found growing wild in most of the Mediterranean countries. It is frequently referred to in Hebrew Scriptures and was probably one of the earliest cultivated fruits of the eastern Mediterranean lands.

The fig (*Ficus carica*) is a medium-sized tree reaching heights of 18 to 20 feet, with rough branches, palmately lobed leaves, and compound fruits. While it is widely grown in the tropics and subtropics, the principal centers of commercial production are in the Mediterranean countries, especially in the hotter, drier parts of these areas. Southern California is a minor producer.

Although there are numerous varieties, the Smyrna fig is of outstanding commercial importance because of its flavor and size. It depends for its fertilization on the fig wasp (*Blastophaga grossorum*), an insect that spends part of its life cycle in the fruit of a wild variety. When Smyrna figs were first introduced into California, the trees grew successfully and blossomed, but failed to bear fruit. Only after the role of the fig wasp had been studied in Asia Minor, and the wild fig and wasps had been obtained, did fig culture become a success.

Fresh figs are a favorite fruit in the producing districts, but since they are highly perishable the trade deals chiefly in preserved or dry figs. Italy is the largest producer, and next is Turkey, where figs are grown extensively along the coast of Asia Minor. The chief shipping port is Smyrna, whence the commercial name for the variety is derived. All the other Mediterranean countries are important producers, and most of them are also important exporters, particularly Spain, Algeria, and Greece. In the United States, California produces nearly all figs that enter commerce. Texas, with a small production, has the distinction of being one of the few centers of commercial fig production outside the summer-dry subtropical region. Most figs imported into the United States come from Greece and Turkey.

PRUNES. While plums occur in many countries and climes, only a few varieties are so firm and sweet as to cure instead of spoil under natural drying conditions. The term *prunes* technically refers to plums that have been dried without removal of the seed; popularly, however, the term covers also the fresh fruit from the districts where the general practice of drying into prunes prevails. Prunes grow best along the cooler and somewhat moister margins of the Mediterranean climates. Yugoslavia is the most important producer. Although a large percentage of the fruit is used in the manufacture of prune brandy and jam, the exports of prunes from Yugoslavia in some years have exceeded 23,000 tons, most of them going to neighboring countries.

As late as 1890 the United States imported more than 27,000 tons of prunes a year. Plantings in California, especially in Santa Clara County, south of San Francisco, proved so successful that California became, for some years, the world's leading prune producer. Prunes also grow well in the mild climates of Oregon, Washington, and parts of Idaho. Several varieties are grown, making fresh fruit available from June to November and providing dried fruit throughout the year. The United States is an exporter. The principal markets are Canada and the countries of northwestern Europe, but American prunes are sold in nearly every market of the world. Dried fruits, however, are a decreasing percentage of total fruit exports.

GRAPES. All regions having the Mediterranean type of climate are noted for their grape culture. The grapes are produced for table use as well as for wine manufacture. Southern Spain has long been famous for

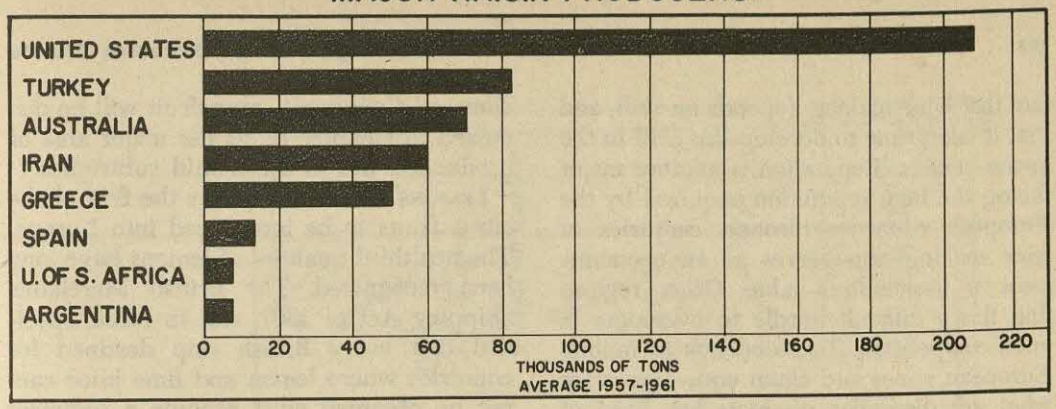


Figure 118.

its grapes of such high keeping qualities that they are available for table use late into the winter. Through modern methods of storage, fresh California grapes are on the market many months of the year.

Raisins, made by drying special varieties of grapes, are among the staple exports of most regions with dry subtropical climate. The center of output of raisins has shifted from southern Europe to California. Machine methods of cleaning and drying have largely, although not entirely, supplanted the older methods of sun-drying (Fig. 118).

Sultana raisins, made from a variety of richly flavored seedless grapes grown in the eastern Mediterranean area, hold high place in European markets. The sultana grapes are grown especially in Greece, on the islands of the Aegean, and in southwestern Asia Minor, where Smyrna is the export center. Supremacy in raisin production, though not in exports, has passed to California, where Thompson Seedless (sultana) is the leading raisin grape. The significance of this change is shown by the fact that before 1890 the United States imported 16,000 to 18,000 tons per year. The leading foreign market for American raisins is Canada. However, during the 1950's raisin exports of the United States declined significantly from 75,000 to about 25,000 tons per year. Greece and Australia are the most important countries of the world in raisin exports. Other exporters are Iran, Turkey, and the United States.

THE WINE-MAKING INDUSTRY. Varieties of grapes suitable for wine production appear to be indigenous to southeastern Europe and southwestern Asia. Their utilization for the manufacture of wine is one of the oldest known industries, and the Old Testament references give evidence of the high favor in which wine was held by ancient peoples. Because of the rather low winter rainfall and prolonged summer drought of Mediterranean countries, good water is not readily obtainable even now in many places. Wine was a thirst-satisfying drink that did not convey disease and could readily be stored for use when needed.

From an American point of view, the amount of wine produced by the leading Mediterranean countries appears enormous. World output has mounted to over 22 million metric tons annually, Italy alone accounting for 5 to 6 million tons per year. France is the next important producer, and other countries of high rank are Spain, Algeria, and Portugal. Although approximately 70 to 80 per cent of the wine is consumed in the countries where produced, it is nevertheless a leading export. In Spain, and especially in Portugal, the wine exports are among the important sources of national income. Northwest Europe and Canada are the principal markets, but Mediterranean wines are shipped to nearly all parts of the world, including the United States.

The other regions of dry subtropical climates—California, central Chile, South Africa, and southern Australia—have wine industries, but none has approached those of the Mediterranean countries and parts of France and Germany in economic importance. This may be partly due to the fact that some areas produce excellent wines, and other areas, often quite close by, do not, for reasons that are not well understood. It may also be partly owing to the

fact that wine making depends on skill, and that it takes time to develop this skill in the newer centers. Reputation is another major factor; the high reputation acquired by the European countries through centuries of wine making now serves as an economic asset of tremendous value. Other regions find this a difficult hurdle to overcome in open competition. The tendency to imitate European wines and claim equivalence for what are dissimilar products has been of doubtful benefit to certain of the non-Mediterranean wine regions.

The citrus fruits. The orange, lemon, lime, and grapefruit, together with several other citrus fruits less widely known, are important commercial products of the subtropical lands. In a way they may be said to be commercially the advance guard of the tropical fruits to enter cool-climate markets. The two qualities which are most effective in promoting trade in citrus fruits are, first, their acidic flavor combined with pleasant taste and health-promoting qualities and, second, their thick, oily, and bitter skins, which serve to protect them from insects and from bruises in shipment. The warm subtropical to tropical lands of southeastern Asia—China and Indochina—are the ancestral homes of the citrus fruits. From southern Asia, sweet oranges were introduced into the Mediterranean countries by the Portuguese in the latter part of the fifteenth century, and thus the beginning was made of an important and enduring industry. From Spain the citrus fruits were carried to the New World, and they are now cultivated in nearly all the tropical and subtropical lands of the world (Fig. 119).

Citrus fruits are produced most successfully under conditions of high temperatures and sunny days. The dry subtropical regions lack a sufficiency of rainfall during the warm season, but where water can be supplied by irrigation, conditions are optimum for growth. Inasmuch as oranges and lemons are of leading commercial significance in regions of Mediterranean climate, they will be discussed here, although areas of important production also lie in regions of humid subtropical and tropical climates. Conversely, grapefruit will be discussed in Chapter 12, as the major area of production lies in the humid subtropics.

LEMONS. The lemon was the first of the citrus fruits to be introduced into Europe. The healthful qualities of lemons have long been recognized. The British Merchants Shipping Act of 1867, still in force, specified that every British ship destined for countries where lemon and lime juice cannot be obtained must provide a sufficient supply to give one ounce of such juice daily to each member of the crew. This measure was intended to prevent scurvy; its effectiveness is now known to be due to the high vitamin content of citrus fruit.

The lemon tree does not grow tall; it rarely reaches a height of more than 10 to 12 feet. A mild climate with much sunshine and without freezing temperatures, with fertile soil and an ample water supply, are the essentials for successful lemon production. In southern California 12 inches of irrigation water per year are needed to supplement the natural rainfall. The crop is picked during winter and spring and stored to meet the heavy summer demands.

The two most-feared dangers are fungus diseases and frost. A fungus disease has caused serious losses to the lemon growers of Italy. To prevent this fate, the growers in California take great care to insure access of ample light and air to all parts of the tree. Pruning is scientifically done, trees are spaced so as to avoid overcrowding, and spraying is carried on methodically to destroy insects and to limit fungi. When danger of freezing is imminent, oil-burning heaters are placed throughout the groves, and if possible a liberal supply of water is run into ditches and laterals. These operations involve care and cost, but results have justified them.

The United States (California) is the world's principal lemon producer, with a harvest of 450,000 to 680,000 metric tons annually. The imports, which averaged 90,000 tons annually from 1909 to 1913, have been negligible since 1937. Italy, long the unchallenged leader, now stands second, with an annual production of about 400,-

MAJOR CITRUS AND OLIVE GROWING REGIONS

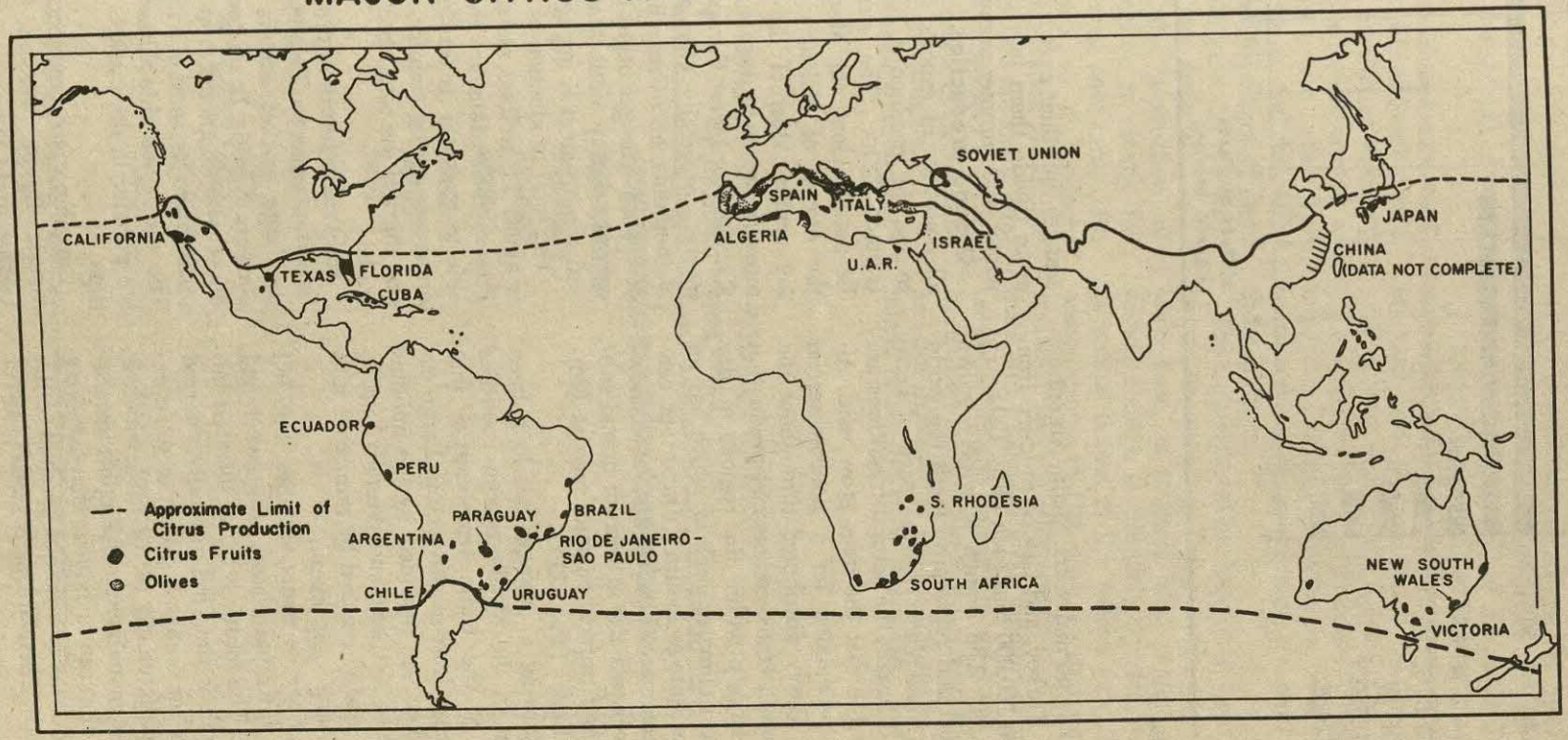


Figure 119.

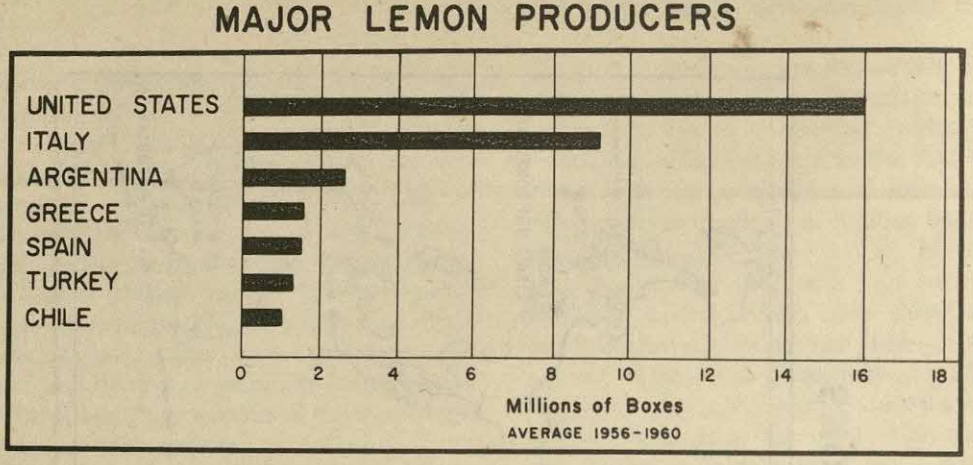


Figure 120.

000 tons in normal years. Spain, Argentina, Mexico, Turkey, and Greece produce from 50,000 to 100,000 tons each (Fig. 120).

ORANGES. The orange is widely grown in tropical and subtropical lands the world over. In some places, such as parts of Paraguay and Brazil, the natural conditions are so favorable that the trees grow wild. Although production on a noncommercial scale is widely distributed throughout the warm humid lands, commercial production centers largely within the regions of dry subtropical climates, each of which has an important orange industry. Important centers of commercial production have, however, developed also in areas of humid subtropical and tropical climate, such as Florida and Brazil (Fig. 121).

The growing of oranges has long been important in the Mediterranean countries because of the warm temperatures that favor such a frost-sensitive crop. Large export markets are provided by the millions of people of Northern and Western Europe who are readily reached by numerous railroad and steamship lines.

Oranges are of many varieties, but fall into two principal classes: the sweet and the bitter. The former is by far the most important and is the kind generally referred to. The bitter orange is grown to some extent in Spain, chiefly for its rind, which is used in the manufacture of English marmalade and curaçao, a liqueur that has long had world fame as a unique product of the Netherlands. There are many kinds of sweet oranges, but their ripening periods are such as to divide them into two main groups: winter and summer oranges.

Orange production. Spain now leads all countries in exports of oranges but is second in production, surpassed by the United States. The producing districts lie mainly along the Mediterranean coast, the *huerta* of Valencia being the leading center. Most of the Spanish oranges move by water to the countries of Western Europe. Northwest Europe is the principal market, especially Germany, France, the Netherlands, and Great Britain. Shipments of Spanish oranges begin in November and continue heavy until May or June, after which movement is negligible.

The total production of oranges in Spain is about 1.5 million metric tons per year. Present indications are that Spain will be able to maintain its leading position as an orange-exporting country, furnishing about one third of the total entering international trade.

Italy ranks fourth in production but is an important exporter, favored by proximity to the large market centers of central and northern Europe. Israel, too, is a major producer with an annual crop of half a million tons of oranges, most of which are exported. The distinctive thin-skinned Jaffa oranges are popular in the markets of Western Europe.

Less important producers of oranges are Algeria, Egypt, Morocco, Greece, Turkey, Tunisia, and Cyprus. As a whole, the Medi-

erranean region promises to hold its place as a major citrus-fruit-producing area, favored as it is by soil and climate and by ready accessibility to the world's greatest markets.

Oranges have been produced on a commercial scale in the Republic of South Africa and in Australia for a number of years. In South Africa production has amounted to around 300,000 tons in recent years. The British Isles, West Germany, and the Netherlands provide the most important markets for South Africa, while most of the Australian exports go to New Zealand.

Except in Brazil, the production of oranges in South America is chiefly for home consumption. Brazil now ranks fifth after the United States as a producer of oranges. Annual production is around two million tons, but exports are small. Brazil produces the navel—a seedless so-called winter orange also important in California—and markets it during our summer.

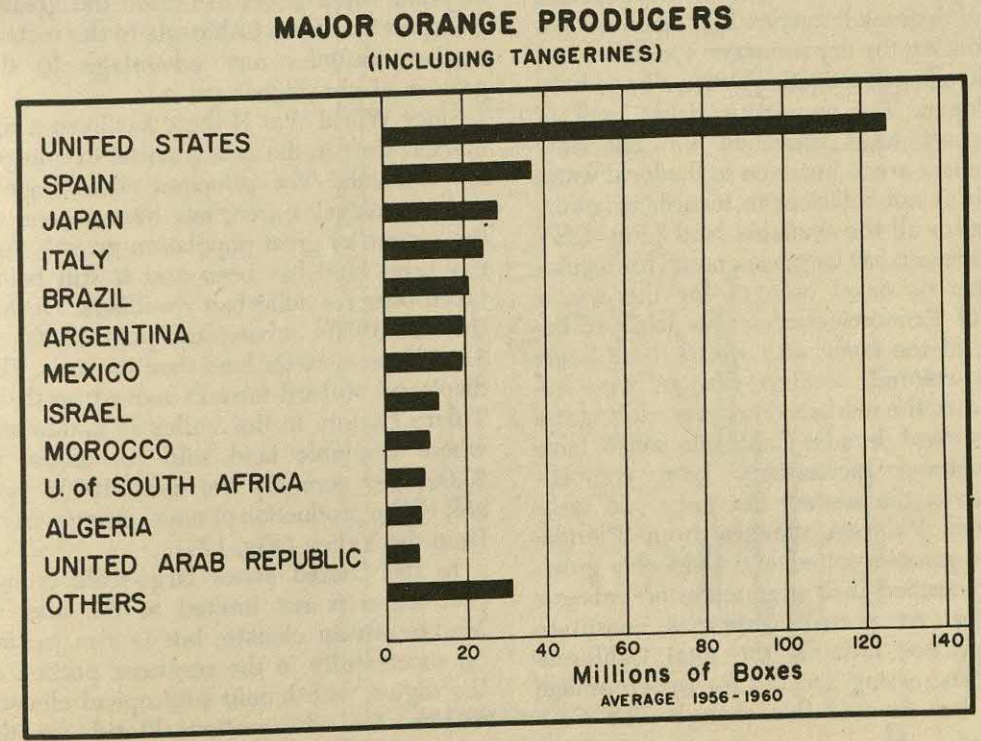
China, the probable home of the orange, is an important producer, but complete data as to quantities are not obtainable. Most of the oranges are consumed locally and do not enter the channels of foreign trade.

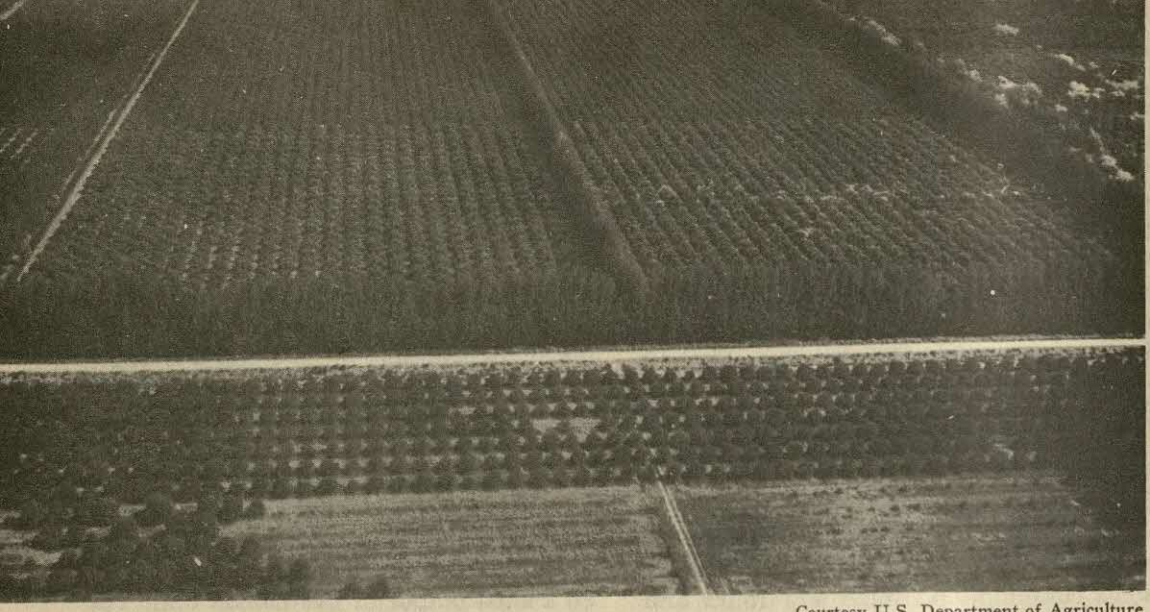
In orange production Japan is significant. About 75 per cent of the Japanese "oranges" are tangerines, known also as *mandarins*.

Of course, neither Japan nor China has the Mediterranean type of climate. Oranges are grown without irrigation in the humid subtropical areas in the southern parts of those countries.

The United States has become the world's largest orange-producing country, and the trend here, as in most other orange-producing centers, is definitely upward, with an annual output of five million tons. The orange groves of California, located in the area that has a Mediterranean type of climate, are subject to a fair amount of winter cold, but the damage is not great because the temperatures are rather stable and not interspersed with warm spells that might bring the trees into active growth.

Figure 121.





Courtesy U.S. Department of Agriculture

Fig. 122. While commercial citrus production is very important in areas of Mediterranean climate, there is also important production in areas of tropical and of humid subtropical climate. The latter is illustrated by this view of citrus groves near Vero Beach, Florida. Note the windbreaks, and also the poor stand in foreground due to insufficient control of the ground water table.

For protection against frost, nearly all orchards are equipped with oil-burning heaters which can raise the air temperature several degrees. Irrigation is of course necessary during the dry summers. Extensive and highly efficient irrigation systems have been developed. The mountains rising back of the coast have furnished the necessary catchment areas, but even so the local water supply is not sufficient to furnish irrigation water for all the available land (Fig. 122).

California has long been noted for its production of navel oranges for the winter market. Economic success was achieved because of the favor with which these large, richly colored, seedless oranges were received in the markets. However, during the past several decades California navels have encountered increasingly keen competition from the seeded, but juicy and well-flavored Valencia oranges from Florida. Lower prices resulted, and California growers intensified their production of Valencia oranges. At present Valencias constitute about three fifths of the total California crop. Increasing demand for frozen orange juice has favored this change. The California navels still bring higher prices than Florida oranges in eastern markets, though in years when prices are close the greater transport cost from California to the eastern markets nullifies any advantage to the grower of the higher price.

Since World War II there has been a significant shift in the area planted to oranges in California. The principal citrus region, the Los Angeles area, has become one of the regions of great population growth. Agricultural land has been and is still being taken over for suburban dwellings. During the late 1950's subdividers paid $7,000 to $10,000 per acre for land then in citrus. The displaced orchard farmers moved north, to Tulare County in the Valley of California, where available land sold for $2,000 to $3,000 per acre. By the early 1960's over half of the production of navel oranges came from the Valley (Fig. 123).

In the United States large-scale orange production is not limited to the area of Mediterranean climate, but is also carried on successfully in the southern portion of the region with humid subtropical climate, and in a few other sections. Florida was the

earliest region of large production. After the Civil War northern Florida found orange production highly profitable, and extensive plantations were established. Several setbacks by cold waves caused moderate losses, until the bad freezes of the winter of 1894-95 finally killed most of the trees. This disaster led to a shift in the center of commercial orange production to the central and southern parts of the state, where killing freezes are less likely to occur. Since 1920 great expansion has taken place, and Florida has reached a high place in the winter Valencia juice-orange trade.

A third much smaller center of orange production developed in the lower Rio Grande Valley of Texas. This area is marginal for orange production because of occasional cold spells in winter which freeze out significant numbers of trees. Despite this hazard the cash return from orange growing is so much greater than that from other crops that growers continue to replant after each freeze. The area accounts for around four per cent of orange production in the United States. Arizona has a small production of both navel and Valencia oranges, while Louisiana produces token amounts of both oranges and tangerines.

In the area of humid subtropical climate of the United States, from the delta of the Rio Grande river to the coastal regions of the Carolinas, every winter cold air masses, the "northers," sweep down from the interior to the sea. This makes the growing of citrus fruits somewhat hazardous, except in regions where there is good air drainage and where temperatures are modified

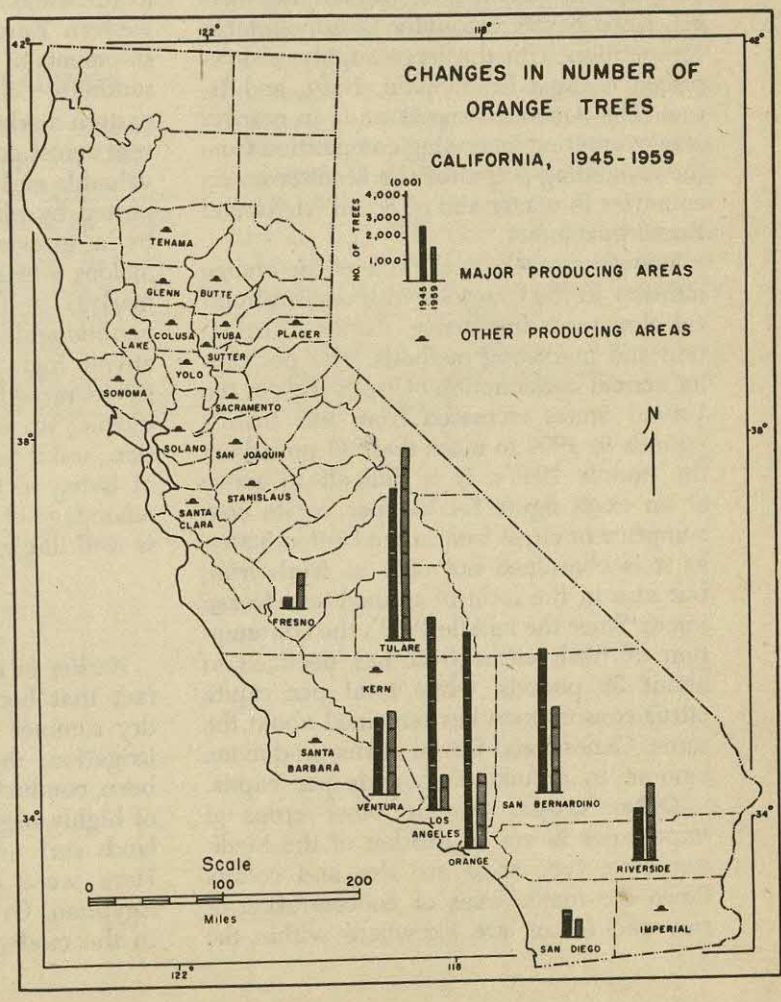


Figure 123.

slightly by numerous water bodies, as is the case in central and southern Florida. In all sections there is always danger of occasional abnormally low temperatures, with consequent harm to the citrus crop, as well attested by events in northern Florida and, more recently, in the lower Rio Grande Valley of Texas.

There is a striking upward trend in orange growing in the United States. Average annual production increased from 21 million boxes in 1915-19 to over 120 million boxes in 1958-62.

The market for American oranges is primarily domestic, and until recent years the United States exports were confined largely to the Canadian market. The larger crops of later years led to the shipment of sizeable quantities to Europe, notably to the United Kingdom. These shipments have been mostly Valencias for the summer market, since navels encounter insurmountable competition with the large supply of low-priced oranges from Spain, Italy, and Israel. The American export trade in oranges is encountering increasing competition from the expanding output of the Mediterranean countries in winter and of South Africa and Brazil in summer.

Viewed as a whole, the role of the orange industry in the countries with dry subtropical climates is impressive, thanks to irrigation and marketing methods. The per capita annual consumption of fresh fruit in the United States increased from less than 7 pounds in 1900 to more than 60 pounds in the middle 1940's. It is difficult to arrive at an exact figure for the per capita consumption of citrus fruit in the United States, as it is consumed not only as fresh fruit, but also in the form of canned and frozen juices. Since the middle 1940's the consumption of fresh citrus fruit has declined to about 38 pounds, while total per capita citrus consumption has remained about the same. Canned and frozen citrus production amount to around 60 pounds per capita.

Other crops. Among other crops of importance in one or another of the Mediterranean type areas are rice and cotton. Since the major areas of concentration of rice and cotton are elsewhere within the tropics and subtropics they will be treated in detail later. It is enough to note that there are small but highly productive areas of rice production in the Po Valley of Italy. Greece, Turkey, southern France, Spain, and Portugal produce lesser amounts. The Valley of California also has rice production.

Cotton is produced in Turkey and Greece and to a lesser extent in Italy and Spain. In recent years cotton has been grown under irrigation in the southwestern states of the United States, including the Mediterranean type areas of California.

Early fruits and vegetables. The Mediterranean climates are centers of production of early fruits and vegetables for Northern markets. There is an increasing shipment of so-called *primeurs,* early potatoes, vegetables, and fruits from northern Africa, Spain, southern France, and Italy to the areas of dense population in northwestern Europe. In the United States the shipments of melons and head lettuce from southern California to the northern and eastern markets call for trainloads of freight sent across country at express speed. Highly valuable early products may even be transported by plane. Central Chile is profiting by a growing trade in fresh fruits and melons which can be sold in the northern markets in winter when local produce is unobtainable. Early markets are always relatively high-priced markets. Thus the ability to provide out-of-season produce is of distinct advantage to the centers of production, and it adds materially to the standards of living in the areas served. The mutual advantage of trade to both seller and buyer is well illustrated in this traffic.

CONCLUSION

Earlier in this chapter we mentioned the fact that because of the handicap of the dry summer and the necessity to develop irrigation, the Mediterranean climate has been conducive to the early development of highly organized forms of society in the lands surrounding the Mediterranean Sea. Here were the centers of the Hebrew, Egyptian, Greek, and Roman civilizations. In the modern world, regions of this type

of climate include progressive centers in Australia, South Africa, central Chile, and California. These regions present a diversity of activities and products unexcelled anywhere. Their winters, with mild temperatures and invigorating sunshine, attract visitors and settlers by the thousands. Their surpluses of fruits and vegetables are important additions to the world's food supply. All in all, the world of today owes much, in heritage from the past and in production of the present, to the lands with this type of climate.

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12

The Regions of Humid Subtropical Climate

areas of transition

THE HUMID subtropical climate of the eastern sides of the continents contrasts distinctly with the Mediterranean climate of the west coasts. The climate of the eastern sides has a greater seasonal range of temperature, since its winters are apt to be colder, and there is rainfall not only in winter but also in summer. In southern China, in fact, it is the winter season that is relatively dry.

CHARACTER AND DISTRIBUTION OF HUMID SUBTROPICAL CLIMATE

The humid subtropical climate, most extensively developed in the southeastern United States and southern China, prevails in the eastern parts of all land masses of continental size between the latitudes of approximately 25 to 35 degrees from the equator (20 to 30 degrees in China). (See Map of World Climatic Regions.) It sometimes is called the cotton-belt climate because of the importance of cotton production in some of the regions. This type is transitional between the tropical climates toward the equator and the intermediate climates poleward; unlike the Mediterranean climate, it lacks a unique, distinctive character.

Temperature. The humid subtropical regions have growing seasons of 10 to 11 months, but there is probability of occurrence of frost during one to four months each year. At the equatorward margins there is a probability of frost only during the coldest month, whereas along the cooler margins frosts are expected during the three or four coldest months. The average temperature of the coldest month, however, is above 43°F. (6°C.), so that in many places there is but relatively brief interruption of growth of the hardier types of vegetation.

Summers are warm, but do not register the extremely high temperatures reported from the interiors of the continents farther poleward. For example, in midsummer a trip from Kansas City, Missouri, to New Orleans, Louisiana, is likely to carry one from scorching heat to warm, though humid, summer weather. In Louisiana and the southern portions of Mississippi, Alabama,

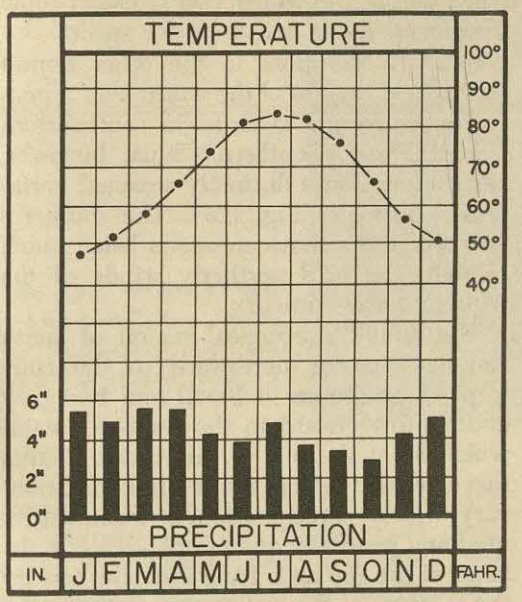


Fig. 124. Humid subtropical climate. Average temperature and precipitation, Vicksburg, Mississippi. Altitude 247 feet, total precipitation 52 inches.

and Georgia practically all summer days show thermometer readings well below the maxima reached on the plains of Nebraska and Kansas. Nevertheless, the summers in this area are enervating because the nights are warm, the humidity is high, and summer is much longer than it is farther north. The "sensible" temperatures, that is, temperatures as felt by the human body rather than read off the thermometer, are relatively high (Fig. 124).

The winters are mild, and much vegetation remains green throughout the coldest months. Snowfall is rare in the warmer latitudes and occurs only during the severest weather in the cooler areas. In the United States the most distressing features of winter are the cold waves which occur when masses of cold continental air from the interior penetrate all the way to the Gulf Coast and eastward to the Atlantic, causing severe damage to crops and physical discomfort to man. In China, also, winter temperatures are rather severe in the lowland areas along the Yangtze river, which are exposed to the sweep of cold winds from the interior, whereas regions which are near the coast or protected by mountain ranges, such as the Szechwan basin, have mild winters.

In the humid subtropical regions of the Southern Hemisphere, temperature changes during the winter are much less pronounced than in similar regions in the Northern Hemisphere. This is due to the predominance of marine influence, which, in turn, is a result of the lack of land masses poleward. Winters are milder, and temperatures less variable.

Winds. The winds are generally light and variable. In the summer warm tropical winds predominate. This is particularly true in China and the United States because of the monsoonal conditions brought about by the large land masses of Eurasia and North America. In North America monsoonal phenomena are comparatively weak and intermittent; in southeastern Asia they are pronounced and persistent during the summer. As winter approaches, the belt of cyclonic storms reaches these regions, becoming dominant in the cooler portions, but only partially so in the warmer. In the United States, the cyclonic storms, accompanied by occasional cold waves, are encountered more and more frequently, and their effects become more marked as one goes northward from Florida to the Carolinas. In China the inblowing monsoon dominates the summer weather, and cold, outblowing monsoon winds rule that of winter. (See Figs. 57, 58, 125.) The climate of southern China therefore exhibits greater seasonal differences than do other humid subtropical areas. The winters are drier and cooler than one would expect judging by the latitude, whereas in other regions the winters are short, mild, and rainy.

During the latter part of summer, tropical hurricanes occasionally reach the coasts, causing serious damage to crops and shipping. They constitute a menace to orcharding and city building that must be reckoned with along the Gulf and South Atlantic coasts of the United States and in southern China, Tonkin, and Japan. Since these late summer storms are most likely to occur when crops are approaching the harvesting stage, they often cause severe losses. Dam-

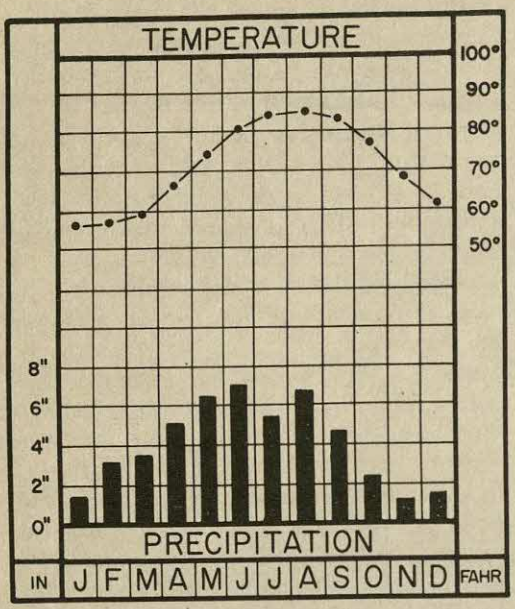


Fig. 125. Humid subtropical climate (monsoon variant). Average temperature and precipitation, Amoy, Southern China. Altitude 12 feet, total precipitation 47 inches.

ages to orchard crops may be especially serious because often the trees as well as the fruit are destroyed.

Rainfall. The rainfall is fairly heavy, the annual average ranging from about 35 to over 60 inches. On the whole, the average is more than double that in regions of Mediterranean climate. Furthermore, except in China, the rainfall is more evenly distributed throughout the year. In southeastern United States there is no prolonged dry period (Fig. 124), but since the autumn usually receives less rain than do the other seasons it is often called dry. Most of the precipitation occurs as rain, although some snow falls every winter in the northern sections. Along the southern margin snow is rare, in some places unknown.

The high relative humidity which prevails in winter sometimes causes even the mild temperatures of that season to feel raw and disagreeably cold. Since the houses as a rule are not built to withstand cold and are not provided with heating systems, during the winter poorly clad people shiver and shake and hope for spring.

Rainfall conditions in the other humid subtropical regions of the world bear a general resemblance to those in southeastern United States. Southern China, however, has a much more distinctly seasonal variation in rainfall (Fig. 125). The southerly winds of the summer monsoon bring much rainfall; the cold northerly winds of the winter monsoon are dry.

The humid subtropical region of South America extends northward to the truly tropical conditions in Brazil and Paraguay and southwestward to the semiarid plains which lie at the foot of the Andes. Within this extensive region, the rainfall conditions vary widely. Precipitation is well distributed and generally quite dependable in the heart of the Río de la Plata area, but toward the margins of the region, especially on the westward front, it is lower and less dependable. Severe droughts, which often result in heavy losses in grain and forage crops, are not infrequent there.

Native vegetation. Under prevailing conditions of abundant rainfall and moderate temperatures, forests are the predominant native vegetation, as they are in humid lands bordering to the north and south. The humid subtropical lands lack a distinctive vegetation type of their own. Savannas, or grassy plains, are usually limited to areas such as occur in some of the low-lying islands and near the coast of the Carolinas, where the water table is so high that trees will not thrive. The Argentine Pampa is a conspicuous exception to this prevalence of forest. Originally the Pampa was a treeless land of tall grasses, forming a closed grass cover in the more humid sections but consisting in many drier areas of separated bunch grasses. The former are the so-called *pasto tierno* areas (soft grasses), the latter the *pasto duro* areas (hard grasses). This prevalence of grass vegetation was probably due only in part to climatic causes, but largely to the fact that much of the Pampa is underlain by eolian loess deposits, or alluvial, redeposited loess. At present little remains of the original vegetation. Much of the land is in crops, and trees have



Fig. 126. Evergreen magnolia tree near Gulfport, Mississippi. Exceptionally large, this tree has an 80-foot spread.

Courtesy U.S. Forest Service

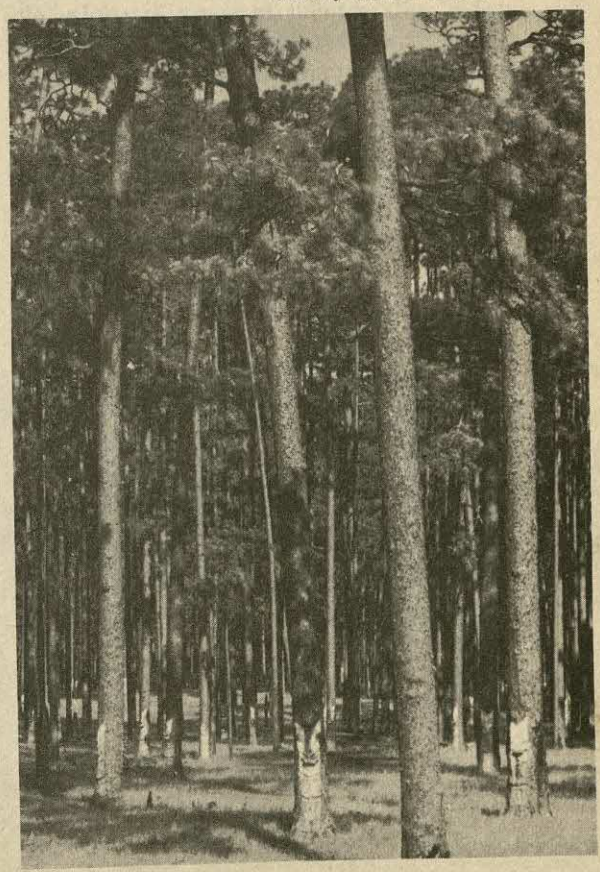
been planted in and around the settlements.

Three broad groups of trees are dominant: the broad-leaved evergreen, the broad-leaved deciduous, and the narrow-leaved evergreen. The first group is an extension of a type common in the tropical rain forests. The other two groups, much the most common in this climate, are extensions from the intermediate climates farther poleward. Where winters are mildest, the broad-leaved evergreens are most numerous, magnolia (Fig. 126) and live oak being among the best known. Thus, along the warm margins of these climatic areas, as in Florida and along the humid Gulf Coast of southeastern United States, in southern China, in northern Uruguay, and in southern Brazil, the broad-leaved evergreen trees predominate on the better soils.

Along the poleward margins the winters are sufficiently severe to induce seasonal leaf fall. In these areas the broad-leaved deciduous forest is dominant on the richer lands. In the United States oaks and tulip trees (called "poplar" or "whitewood" in the South) are the most common representatives. Narrow-leaved coniferous forest is found on the higher lands with thin soils and on lowlands with poor, sandy soils. Thus, extensive pine forests characterize the sandier lands in the United States (Fig. 127), and the *Araucaria,* another conifer, flourishes on the hilly lands of parts of southern Brazil. The southeastern states have been for years the principal source of yellow pine for domestic markets. Until the 1940's little reforestation was practiced, and the timber supply became seriously depleted. Since that time large-scale replanting of seedlings has been so extensive that

Fig. 127. Long-leaf yellow pine forest in Louisiana.

Courtesy U.S. Forest Service



according to the United States Forest Service the net annual growth of saw timber now slightly exceeds the net annual cut.

Soils. Inasmuch as the regions of humid subtropical climates are transitional between the seasonal warm and cold of the middle latitudes and the all-year warm of lower latitudes, and between the humid coastal areas and the drier regions of the interior, it is not surprising that the soils likewise should show transitional characteristics. The influence of the prevalently higher temperatures in the equatorward areas is reflected in the distinctly reddish soils, while in the poleward areas the soils generally have a yellowish color. In the warmest, most humid areas, lateritic soils similar to those described in Chapter 8 are not uncommon. In general, the mature soils are of the groups known as the red and yellow soils.

Because of the high rainfall, the soils are so fully leached that they are weak in lime and other soluble mineral salts and therefore belong to the general group of the pedalfers. Structurally they vary from fairly stable soils, similar to those in cooler climates, to weak soils, such as are commonly found in the tropics. Inasmuch as soils with weak or poor structure entail heavy costs in labor and fertilizers if productivity is to be maintained, wise selection of lands is necessary for successful agriculture.

The alluvial lands are in general the most productive. In southern China agriculture is practically limited to the floodplains along the numerous streams; among these the plains of Szechwan on the upper Yangtze river, the plains of Tungting and Poyan lakes, and the valley and delta of the Si river are the largest and the most densely populated. In Argentina the broad plains of the Pampa have young loessal (eolian) soils of high fertility, to which much credit must be given for the successful agricultural development of that region.

In North America the Mississippi river is bordered by a notable belt of very rich alluvial soil. The upland soils in southeastern United States are, however, relatively poor and require continued application of large amounts of fertilizer and labor for profitable production (Fig. 341). This is a decided handicap when the crops must be sold in competition with those grown on soils that are more fertile and where, therefore, expenses for fertilizer and labor are lower. From a climatic point of view, corn can be raised successfully, and good yields are obtainable; nevertheless, corn is of slight importance as a commercial crop because farther north in the United States it yields more heavily and with less expense for fertilizer. Cotton, like corn, can be grown only with the use of heavy applications of fertilizers, but unlike corn the crop does not have to compete in the market with a crop raised without such expense.

LAND UTILIZATION

Crops. The humid subtropical regions are capable of producing a fairly wide variety of crops, especially on the better soils. The growing seasons are long, the winters are short and mild, and the rainfall is sufficient. However, many areas, such as the sandy regions of the American South or the hilly lands of southern China, have poor soils. Also, in the regions of medium fertility soils leach easily, and the problem of maintenance of fertility must be met.

The transitional character of the humid subtropical areas applies to their crops as well as to their natural conditions. They have few distinctive crops not shared by areas of other climates. In southern China and southeastern United States the warm portions raise subtropical products, and in the extreme south even a few tropical products, whereas the colder margins produce temperate cereal crops. The Pampa region has cooler summers, moderate rainfall, and excellent soils. Partly as a result of these circumstances, corn, wheat, alfalfa, and cattle raising predominate.

In the United States the agriculture of the humid subtropical region is undergoing considerable change. In a rather narrow belt along the coast, but including all of Florida, early vegetables and citrus fruits are important, with smaller areas used for rice and sugar production. In several sections of this area, especially in Florida, beef-cattle rais-

ing is on the increase. In the major portion of the climatic area, formerly the heart of the Cotton Belt, great changes have taken place during the past three decades. Cotton, while still important in the Mississippi Valley and to the west, has declined in the eastern portion, and the growing of peanuts and soybeans has increased, as has cattle raising. In certain areas the production of pulpwood has gained in importance. To the north mixed farming has been practiced for many decades, and cotton, corn, tobacco, and oats are raised, but here we are already outside the area of pronounced humid subtropical climate.

Throughout the region corn breads are a staple food, which they are not in the Corn Belt farther north. Corn also is a major feed for cattle and other livestock, while in Texas grain sorghums are important.

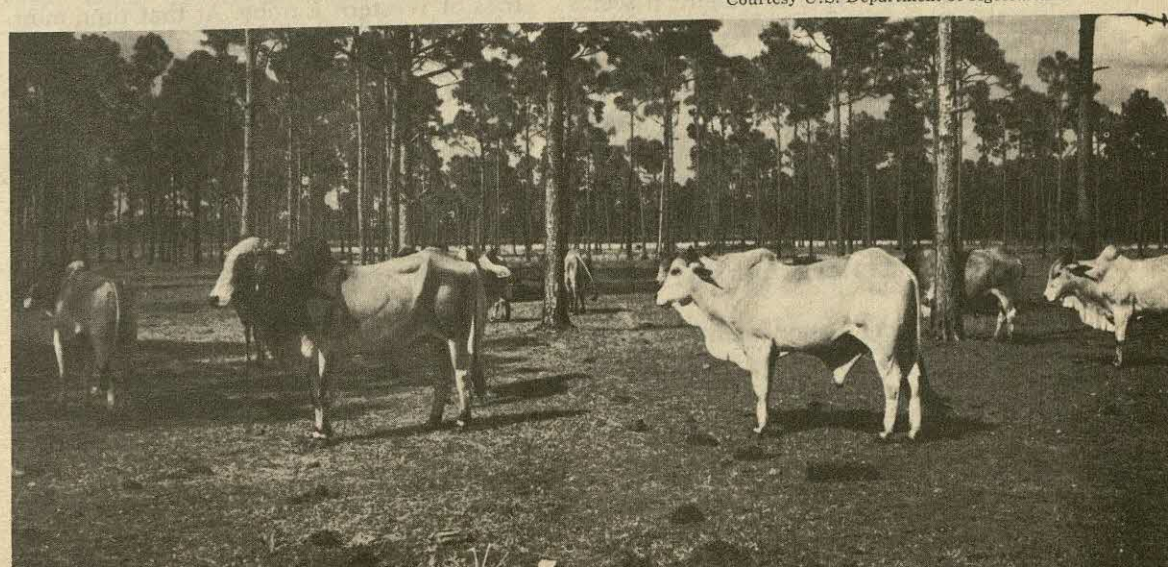
Livestock. Until the late 1940's the humid subtropical region of the United States was unimportant as a producer of beef. These hot, humid areas are not really favorable for Taurine cattle native to the cool lands of Western and central Europe. The unimproved pastures developed on the leached soils of the area produced tough grasses of low nutrient value; insect pests, such as ticks, were more of a handicap than farther north, and land was used for other, more profitable purposes. Over the past decades a number of these factors have changed so as to make beef-cattle grazing a profitable enterprise. Cattle breeds have been altered to produce animals more tolerant of hot, moist conditions, by crossing European type cattle with the humped Indian zebu type. Pastures have been improved by the use of fertilizer and by the development of grasses that are productive under warm, humid conditions. All of these factors have contributed to an increase in importance of cattle keeping, though the area is still far from being self-sufficient in beef or in dairy products (Fig. 128).

The mule was for long the mainstay of cotton production. Working either singly or in a two-mule team, his presence was as essential to the American cotton landscape as the Negro cottage with its chinaberry trees. However, the general introduction of tractors and machine methods of cultivation and harvesting have brought about a change to less picturesque but more efficient methods of production. Mechanization has also resulted in significant decreases in the rural population, especially in the areas away from the coast, as it has farther north and west in the Corn Belt and in the wheat regions (Fig. 16).

Hogs abound, usually lean and fleet of foot, quite in contrast to their rotund cousins of Iowa. Only in a few areas, however, are

Fig. 128. Zebu (Brahma) breeds are resistant to high temperatures combined with high humidity. In humid subtropical areas they are useful for cross-breeding with local high grade stock. Zebu bulls on a "piney woods range" in Florida.

Courtesy U.S. Department of Agriculture



hogs of commercial importance, and then mostly for the production of certain types of ham. Poultry is produced on a large scale in the South. The mode of production consists of broiler factories which turn out frying and broiling chickens in from six to eight weeks. Georgia and North Carolina are among the leading states in broiler production.

In China the great density of population is not conducive to livestock raising, as it is more efficient to utilize food directly than through the intermediary of animals. However, the efficient hog is very important.

In the Pampa region of Argentina the production of beef plays a leading role. For a long time cattle ranching was the only industry in this region, but as the population has increased, cattle raising has been supplemented by the production of wheat and corn for export. In southeastern Australia, also, the livestock industry, especially dairying, is important.

COTTON

The world's greatest area for the commercial production of cotton lies in the western part of the region of humid subtropical climate in the United States and in the immediately adjacent portions of drier and cooler climate to the west and north. Although three decades ago the United States produced a much larger percentage of the world's cotton crop than it does today, it still accounts for about one third. Thus while cotton can be grown commercially in regions with other types of climate, it seems fitting to discuss this crop in this chapter dealing with the humid subtropics.

Climatic requirements. During the period of vegetative growth sunshine must be abundant, and the nights as well as the days must be warm. As a result of these rather exacting temperature requirements, the cultivation of cotton is found only from the tropics to the warmer parts of the temperate zone.

Cotton is a long-season plant, requiring a minimum of 180 to 200 frost-free days for successful cultivation, and from four to five months of uniformly high temperatures during the growing season. The plant makes little progress at temperatures below 60°F.

The cotton plant needs a moderate amount of moisture, well distributed throughout the growing period. An annual rainfall of 25 to 45 inches is considered most favorable. During the harvesting season, however, comparatively dry weather is essential, because the quality of the cotton fiber in the open boll is impaired by rain and high humidity.

Suitable climatic conditions for cotton are encountered in: (1) parts of the areas of humid subtropical climate, (2) in adjacent regions of somewhat cooler or of drier climate, (3) in regions of tropical savanna and steppe climate, (4) in tropical highland areas, and (5) in warm deserts. In regions of tropical steppe climate irrigation is usually highly desirable, and in warm desert areas it is, of course, mandatory. In fact, an increasing proportion of the world's cotton is grown under irrigation. The areas of rainy tropical climate generally lack a sufficiently pronounced dry season, and, on a commercial basis, cotton cannot be produced satisfactorily there.

Historical significance. Cotton was used for the manufacture of coarse cloth by the Indians of northern South America, Central America, and the West Indies before the arrival of white men. It was a cultivated plant in India before the dawn of history and was grown in Egypt as early as the fifth century B.C. Not until the end of the eighteenth century, however, was the cotton fiber first used by the textile industries of Western Europe. At that time most of the raw cotton came from the Near East, although small quantities were imported from the West Indies and the Guianas. The fiber had to be separated from the seed by hand or by primitive machinery. This laborious and costly method made cotton too expensive for general use in cloth manufacture. The invention of the saw-type cotton gin by Eli Whitney in 1793 made possible cheap mechanical separation of fiber and seed.

The spectacular growth of the cotton industry in England and in New England opened the first chapter of the Industrial

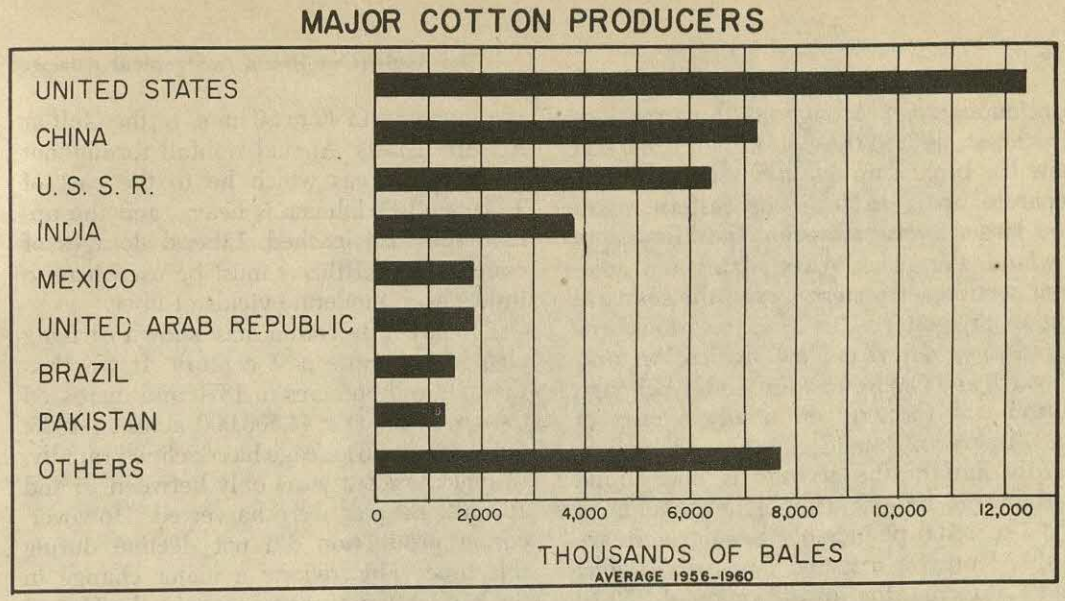


Figure 129.

Revolution. Cheap machine-made cotton cloth began to replace linens and hand-made cottons in many parts of the world, thus creating an immense market. In response to the increasing demand, cotton acreage rapidly expanded, especially in the United States. In the South cotton began its rule which, for better or worse, lasted until the 1940's.

Types of cotton. Cotton is classified and priced on the basis of the length of the fiber or the staple. A difference of $\frac{1}{16}$ inch in length makes a difference of $6 to $8 per bale in price. Additional factors, such as color, determine the grade of cotton and further influence its price. Cotton with a fiber of over $1\frac{1}{8}$ inches is considered long staple, while that of less than $\frac{7}{8}$ inch is short staple. Cotton between these lengths is classified as medium staple. By far the largest part of the world's cotton crop is medium and short staple. Staple length determines the use to which the cotton can be put: the longer the staple, the finer and stronger the yarn that can be spun, and the finer the cloth that can be woven. For the finest cotton dresses long-staple cotton is used. Short-staple cottons make coarse yarns and therefore coarse cloth. Some cottons have such a short staple that they are hardly fit for use in the manufacture of cotton textiles, but they, along with linters (fuzz of cottonseed), are a source of cellulose for the manufacture of rayon.

Principal cotton regions. In cotton areas outside of the United States much harvesting of cotton is still done by hand labor. A competent picker is able to gather about 150 pounds per day. Thus availability of cheap labor is one factor limiting areas of cotton production. Where mechanical planting and harvesting are practiced, large farm size and relatively level topography are essential. Commercial cotton production is limited to a number of fairly sharply defined regions which meet the above labor requirements or which have a topography and other conditions favorable to mechanization and which have adequate temperatures and sufficient soil moisture. The most important of these are located in the United States, the Soviet Union, China, India, Brazil, Mexico, and Egypt (Fig. 129). Centers of lesser importance are in Pakistan, Turkey, Argentina, Peru, Sudan, Uganda, the Congo, Syria, Iran, Mozambique, and in a number of other countries.

Cotton in the United States. The United States during the 1960's produced about a third of the world's cotton and continues to be the dominant producer, although cotton plantings are increasing more rapidly in other areas of the world. At one time cotton was concentrated in a nearly

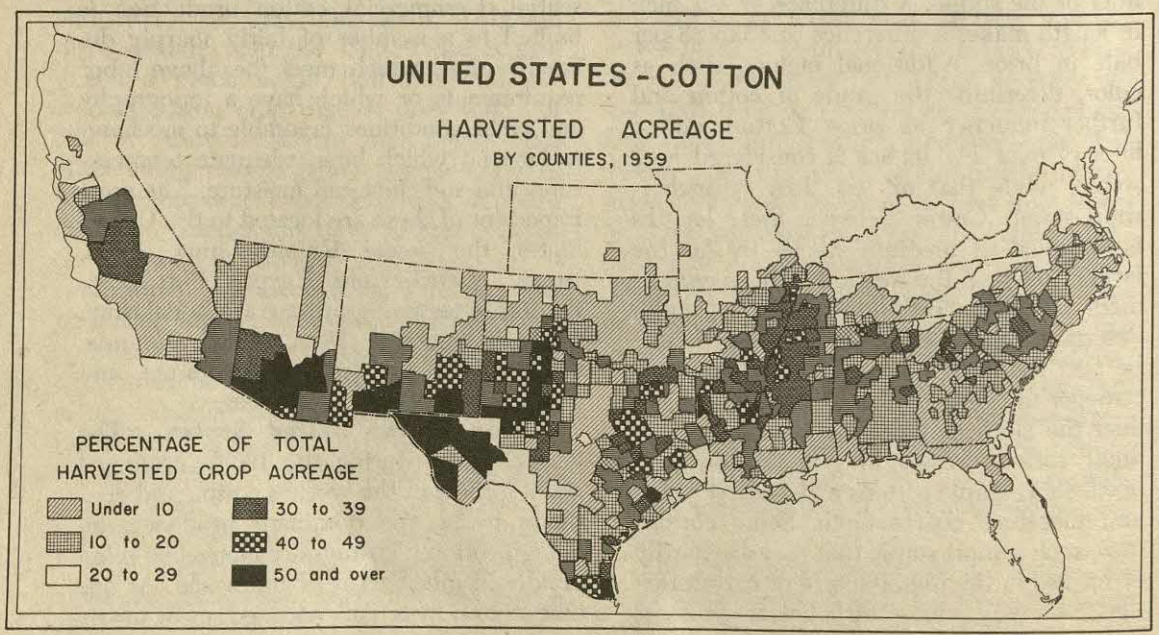
continuous zone throughout the American Southeast, termed the Cotton Belt. This belt now has broken up into a number of small, separate areas in the southeastern states and larger areas embracing the Mississippi lowland, the Black Waxy Plains and adjacent sections of eastern Texas, the semiarid region of western Texas, and various irrigated river valleys in New Mexico, Arizona, Nevada, and California (Fig. 130). Although cotton was formerly essentially a crop of the American humid subtropical region, hardly half of the acreage is now found within this region. The highest yields of 1,000 to 1,100 pounds of fiber per acre are realized on the irrigated lands of Arizona and California, the lowest yields of 350 to 370 pounds per acre occur in the southeastern states and Texas.

In the United States cotton is grown on various types of soil, from sands to light clays, but yields are highest in the irrigated regions of the southwestern states, on the alluvial soils of the wide, flat Mississippi Valley from Cairo, Illinois, to Baton Rouge, Louisiana. Because of high rainfall and high humidity during the harvest season, no cotton is grown in most of Florida, and but little is grown within 40 to 50 miles of the Gulf or Atlantic coasts. Annual rainfall throughout the cotton areas which lie to the east of Texas and Oklahoma is heavy, and the upland soils are leached. Liberal dosages of commercial fertilizers must be used here to insure even moderate yields of fiber.

The area in cotton has shown striking changes over the past century. It was less than 10 million acres in 1870 and increased to a peak of over 44,500,000 acres in 1926. Since that time acreage has declined rapidly, so that in recent years only between 15 and 16 million acres were harvested. However, cotton production did not decline during this time. This reflects a major change in the production of many crops in the United States. Due to improved technology, productivity per acre has increased to such an extent that, while acreage declined, the total quantity produced increased.

The changes in acreage have been accompanied by pronounced changes in distribution. During the 1950's acreage decreased in all cotton-producing regions, but it decreased more rapidly in the Southeast than in the other areas. The irrigated lands of the West now account for 20 per cent of

Figure 130.



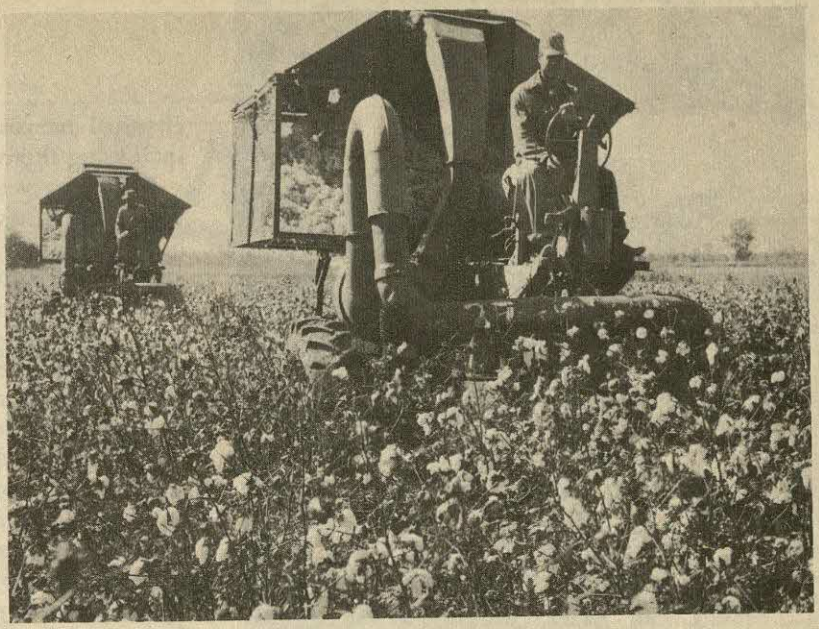


Fig. 131. Mechanical "spindle type" cotton pickers on a large cotton farm, in Mississippi. Larger farms and machinery have, in many parts of the American South, resulted in a sharp reduction of tenant farmers and "hired hands."

Courtesy U.S. Department of Agriculture

the crop, Texas and Oklahoma for nearly 40 per cent, the Mississippi lowlands for 30 per cent, and the Southeast, formerly the dominant area, now accounts for only 12 to 14 per cent. Cotton has remained a major crop in only a few sections of South Carolina, Georgia, and Alabama.

Cotton is still dominant in a broad belt from Cairo to the lower Rio Grande river, a belt that passes through southwestern Tennessee, western Mississippi, southeastern Arkansas, northern Louisiana, and eastern Texas. Another area where cotton is the principal crop lies north and west of Abilene, Texas. In most of Texas and Oklahoma yields of nonirrigated cotton are low, but the farms are larger than in parts of the old Cotton Belt, and since all the bolls ripen at approximately the same time the cotton can be picked mechanically at low cost with little wastage (Fig. 131). The dry climate of these states has proved to be of great advantage in limiting the depredations of the boll weevil, which flourishes in the more humid environment to the east. An added advantage of the region west of Alabama is that the soils are more fertile, so that less fertilizer is needed.

The bulk of the United States crop is essentially of one type. The upland short-staple cotton, the longest of the short-staple cottons and often referred to as "middlings," constitutes more than 99 per cent of the total. It has a considerably longer fiber than the Asiatic cottons, and therefore is in great demand by cotton spinners all over the world. Production of long-staple upland with fibers of 1⅛ to 1¼ inches is limited to certain sections, especially the Pecos and Red River valleys of Texas and lands in the Southwest.

Cotton has put an indelible mark upon the entire economic and social life of the southern part of the United States. The plantation system and Negro labor were largely responsible for the rapid spread of cotton cultivation during the first half of the nineteenth century, introducing a monocultural system of agriculture with all its attendant evils.

The plantation system was succeeded by a system of tenancy, with comparatively small holdings. While not all producers were tenants, for many decades 60 to 70 per cent of the farms in the Cotton Belt were operated by tenants, and in some states the percentage was even higher. However, white farmers produced more than half the crop. With the breaking up of the once-solid Cotton Belt, changes in farm size and changes in the tenancy situation have come. In several of the older areas of heavy production, such as the Yazoo delta, the average size of the cotton farms has increased, and there even have come into existence large, corporation-owned farms. Also in the



Courtesy Association of Commerce, New Orleans

Fig. 132. Cotton bolls open, ready for the harvest. Shows picking by hand. This method of harvesting is still general throughout most of the cotton regions of the world.

newer, western areas large cotton farms are prevalent.

Mechanization of cotton harvesting is comparatively recent. Cotton is a difficult crop to harvest mechanically, as the problem is one of quality control. The human cotton picker discriminates between ripe and unripe bolls and distinguishes between cotton bolls and leaves and twigs, whereas the machine does not do this readily. This difficulty has been responsible for the retarded development of widespread mechanical harvesting. In 1954 about 20 per cent of the cotton produced was harvested by machine. This increased to slightly over half in the early 1960's. The degree of mechanization varies widely. The large-scale irrigated farms of California harvest nine tenths of their cotton by machine, and Texas, almost two thirds; in the Mississippi Valley between 40 and 60 per cent is so harvested, but in the old Southeast not more than one eighth. While the states of the Southeast have been the last to adopt mechanical harvesting, mechanization is also increasing there (Fig. 132).

For many years educational and agricultural leaders have been urging more diversified farming for the South, and their efforts are bearing fruit. The use of soil-building and soil-protecting crops has been encouraged, and contour plowing has become a common practice. Cotton may still be expected to remain a major crop in sections of the American South.

Ordinarily, about 60 per cent of the American cotton crop has been used in domestic manufacturers, and 40 per cent has been exported, principally to European countries and to Japan and India. The principal cotton-shipping ports are Galveston, Texas, and New Orleans, Louisiana.

Other cotton-producing countries: INDIA AND PAKISTAN. Although cotton is widely grown in India and Pakistan, the principal districts lie in the western part of the Deccan Plateau (see Fig. 133). The climate is of the tropical savanna type, with precipitation of 40 inches or less, which is not high in view of the average temperatures. Fortunately, most of this rainfall occurs during the summer, from June to September, and provides a larger supply of moisture for the cotton crop than would a similar amount distributed throughout the year. In the western part of the Deccan Plateau lava sheets, comparable to those of the Columbia Plateau of the United States, have given rise to fertile black *regur* soils which are retentive of moisture and do not need irrigation. Cotton is also grown on the ferruginous soils of the southern part of the Deccan Plateau.

The cotton-planting season in various parts of India and Pakistan ranges from March to October, depending largely on the regional distribution of rainfall. The cotton-picking season, in a similar fashion, extends from September through the dry winter months to April.

In the Punjab or upper Indus plains and in the Sind or lower Indus Valley, irrigation is necessary for cotton culture. The Sukkur or Lloyd, the Gudu and Lower Sind dams provide water storage for extensive irrigation works in the lower Indus Valley.

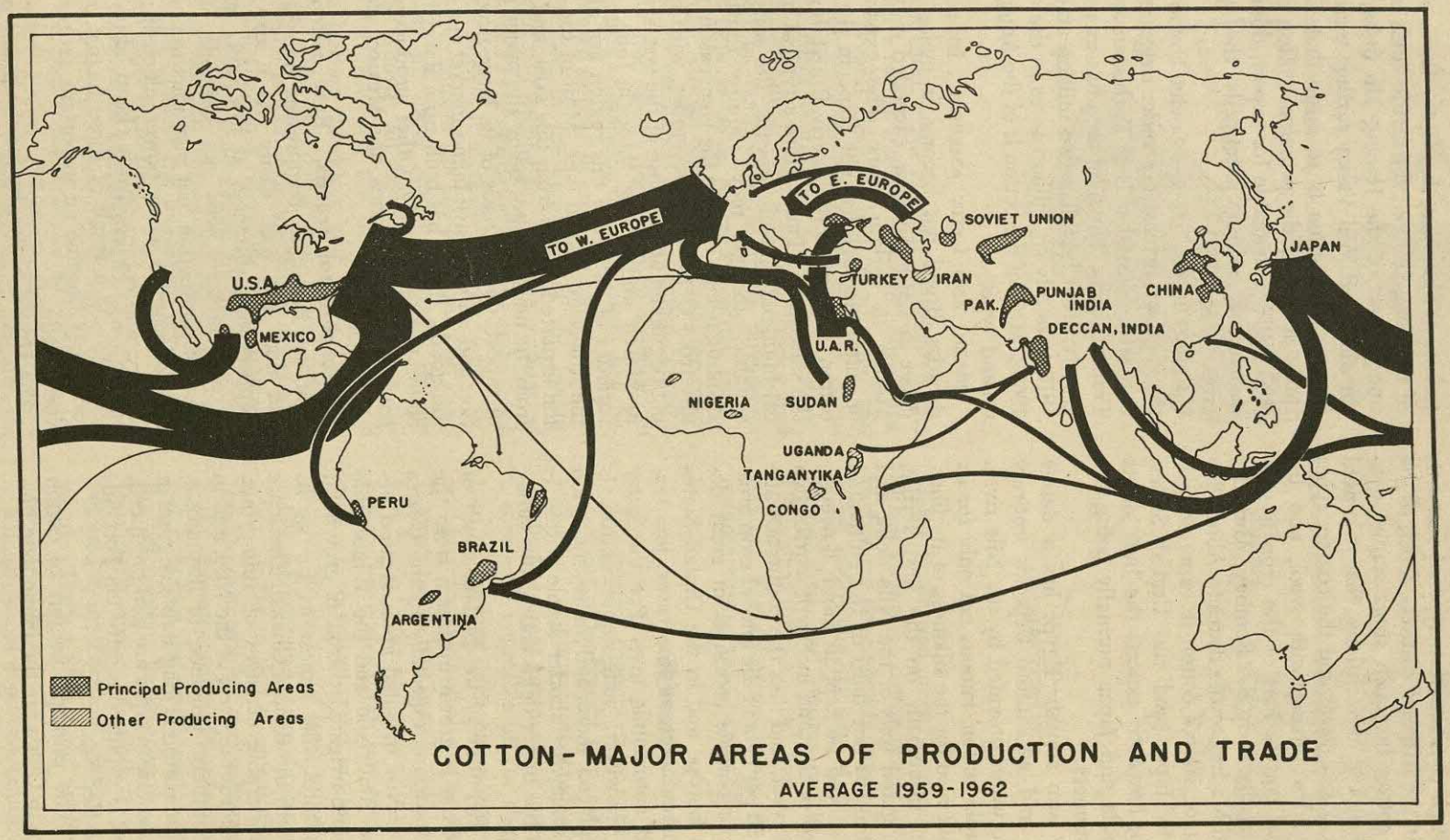

TO W. EUROPE
TO E. EUROPE
SOVIET UNION
JAPAN
U.S.A.
MEXICO
TURKEY
IRAN
PAK.
PUNJAB
INDIA
CHINA
DECCAN, INDIA
U.A.R.
NIGERIA
SUDAN
UGANDA
TANGANYIKA
CONGO
PERU
BRAZIL
ARGENTINA
Principal Producing Areas
Other Producing Areas
COTTON - MAJOR AREAS OF PRODUCTION AND TRADE
AVERAGE 1959-1962

Figure 133.

Although the American type of cotton is grown in the irrigated districts, much of the Indian cotton has such short staple, generally ½ to ¾ of an inch long, that it is used only for coarse yarns and the coarser types of cloth, for mixing with wool, and for medicinal cotton. Part of the crop is consumed locally or in the Bombay, Ahmedabad, and Madras textile districts. About five per cent of India's cotton is exported primarily to Japan and the United States. Pakistan, however, exports the bulk of its crop, India and Japan normally being the best customers.

EGYPT AND SUDAN. Egypt has a desert climate, and agriculture depends entirely upon the water provided by the Nile river. Long-staple cotton, famous not only for its length but also for the silkiness of its fiber, is grown principally on the low, fertile, easily irrigated soils of the Nile delta and occupies about one third of the cultivated area. It should be kept in mind, however, that much of the land in Egypt carries two crops per year, and thus the cotton acreage is about 20 per cent of the annual crop area. Egypt's long-staple cotton is in great demand in Europe and in the United States for the manufacture of fine yarns, fine textiles, and automobile tires. For the latter purpose, however, long-staple cotton is being replaced more and more by nylon fiber. A somewhat shorter staple cotton is grown in the upper delta and in the valley of the Nile.

In the Republic of the Sudan, south of Egypt, cotton is grown upstream from the city of Khartoum, especially in the Gezira and White Nile irrigated areas located between the Blue Nile and the White Nile rivers. Pump-irrigated cotton is grown far up the White Nile, almost as far as its junction with the Bahr el Ghazal. There are even considerable acreages of rain-grown cotton in Kordofan, west of the Nile, and in the far southern province of Equatoria. Much of the cotton is long-staple, Egyptian type, but American types are also produced. The cotton is exported mostly via Port Sudan on the Red Sea.

CHINA. The principal centers of cotton production in China are the immediate hinterland of Shanghai, that is, the lower valley of the Yangtze river; the fertile lands of the upper parts of the Hwang Ho delta; and the sheltered Wei Valley farther west. Although production is so large that China ranks as one of the principal cotton countries, little is available for export, domestic demand absorbing practically the entire crop. (Fig. 133.)

SOVIET UNION. In the Soviet Union cotton is grown extensively under irrigation on the fertile loessial soils of Turkestan and in Transcaucasia. The total area has increased greatly, from less than two million acres in 1910 to nearly six million acres in the early 1960's. Most of the cotton is of the American upland type.

BRAZIL AND LATIN AMERICA. In recent decades Brazil has become a major producer in Latin America, exceeded only by Mexico in certain years. The expansion of cotton acreage has not come in the old cotton area of northeastern Brazil but in the state of São Paulo. Here a typical tropical highland climate prevails, the soils are suitable, though they require fertilizer. Planting occurs early in the wet season, usually from October to December, with picking beginning at the close of the wet season in March and lasting through June. The varieties of cotton in this region are all of the American upland type. Most of the cotton exported comes from this area, and not from the north, Santos being the major port of export. On the basis of its large production and an extensive home market for cotton goods, Brazil has built up a flourishing cotton-textile industry. Other producers of note in Latin America are Mexico, Peru, and Argentina.

International trends. Raw cotton is light, can be tightly compressed into bales, and does not spoil easily. As it can be shipped long distances at low cost, areas of manufacture need not coincide with areas of production, but manufacturers can choose locations where power, efficient machinery, and comparatively cheap labor are available. As a result of these factors, raw cotton has become an important article in world trade.

The United States, by far the major pro-

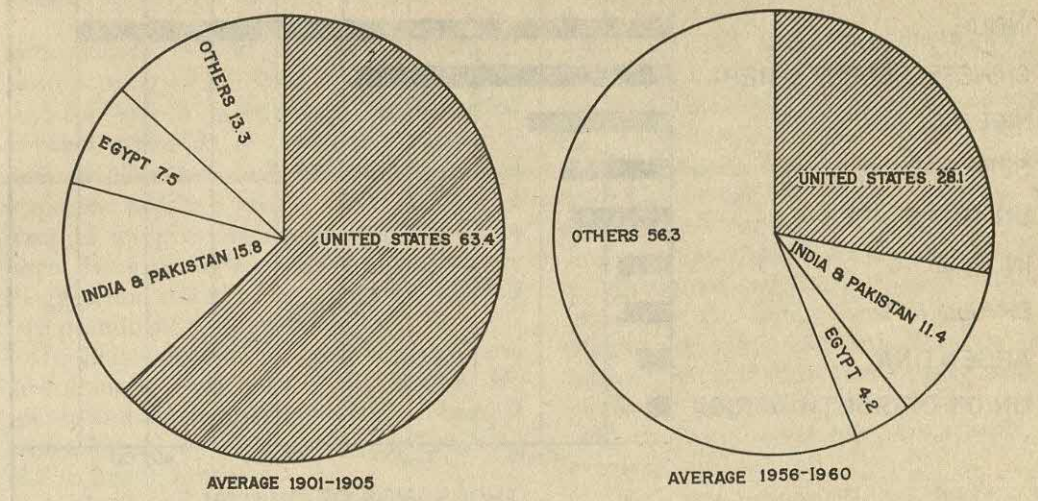


Figure 134.

ducer and exporter, long dominated the world's cotton market. However, during the last several decades both production and exports have increased in many other countries. After World War I several countries, especially the United Kingdom, France, and Belgium, endeavored to make themselves less dependent on American cotton. In the former African colonies of these three countries governmental encouragement caused a slow but steady expansion of acreage. In Uganda, American upland cotton has become an important crop. Cotton production increased in the Republic of the Sudan, Nigeria, Tanganyika, and the nations of former French Equatorial Africa and French West Africa. It increased greatly in the Asiatic portions of the Soviet Union, and practically all other cotton-producing regions have shown an upward trend since the 1920's. However, the United States is still the leading producer and major exporter (Fig. 134). Its continuation in this position depends not only on the favorable natural environment, but especially on mechanized, high-quality production, so that the crop can be sold on world markets at prices low enough to meet the increasing competition from other countries.

Centers of consumption of raw cotton. The principal cotton-textile districts of the world are located in Great Britain, the United States, West Germany, Russia, France, Italy, Czechoslovakia, Belgium, the Netherlands, and other European countries. Other important cotton-manufacturing districts have developed in Japan (Osaka, Nagoya, and Tokyo districts), India (Bombay, Ahmedabad, and Madras districts), China (Shanghai district), and Brazil (São Paulo region). For a further discussion of cotton manufacturing, see Chapter 28.

PEANUTS

The peanut, thought of by most people as something to be bought in small paper bags and eaten at circuses and ball games, is a product of great commercial importance as a source of vegetable oil for the manufacture of cooking oils, oleomargarine, soap, and greasing oils and also as an animal feed. Peanuts thrive best in soils of loose structure which are fertile and neutral to slightly alkaline. They also grow, however, on sandy soils where warmth and moderate rainfall prevail throughout a long growing season.

Climatically, the range of peanuts is somewhat similar to that of cotton. Peanuts are produced in tropical and subtropical lands, and even poleward of the subtropics. In the latter regions the seed remains smaller and the oil content lower than in the former. Important centers of production have developed in southern and eastern Asia, southeastern United States, and western Africa. (See Fig. 135.)

The principal exporting countries are Ni-

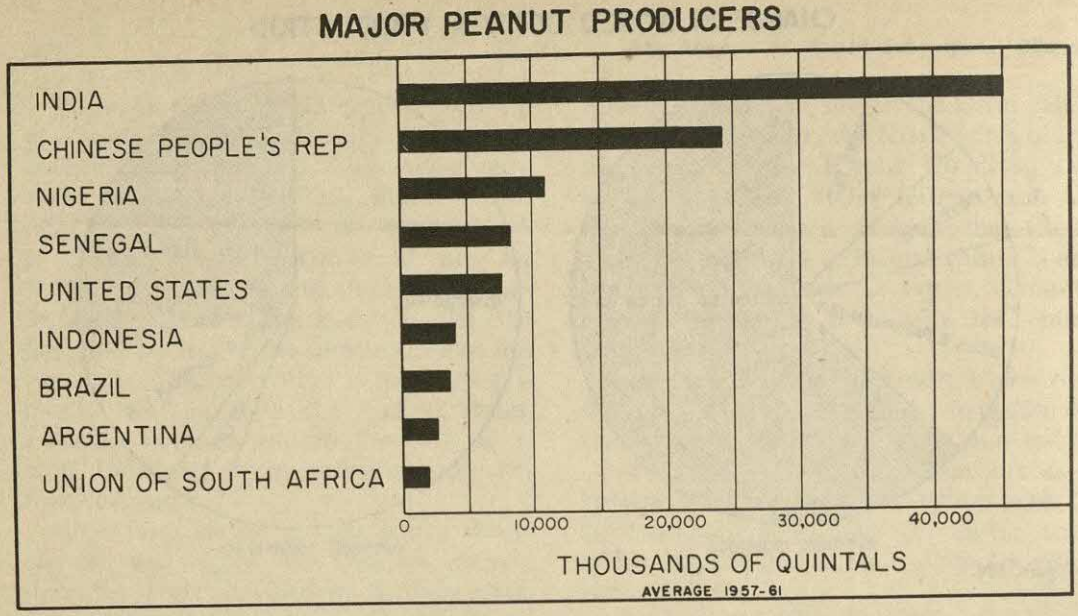
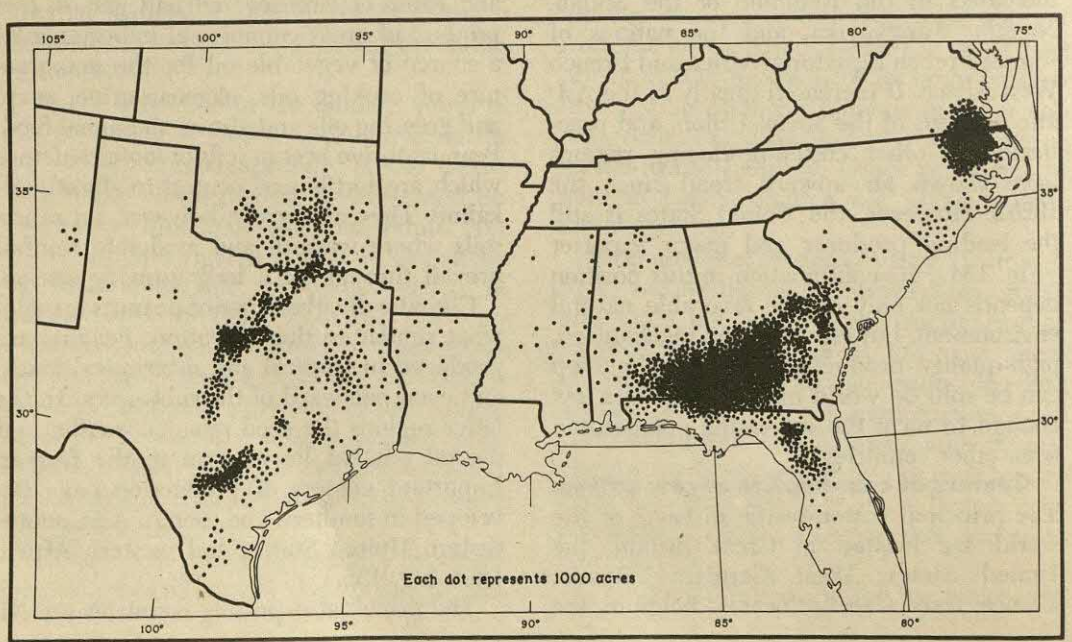


Figure 135.

geria, Senegal, Ivory Coast, China, and, in some years, India. Exports from India are erratic, being quite large in some years and minimal in others, a matter governed largely by size of harvest and the huge internal demand. The major source areas of peanuts for export shifted from southern Asia to Africa during the years of World War II. In Africa the principal growing areas are found in northern Nigeria around the ancient city of Kano, former terminus of trans-Saharan camel routes; in Senegal, inland of the port of Dakar; and in the Bamako-Ségou region along the upper Niger river. Peanuts consti-

Figure 136. Peanut acreage in southern United States (peanuts grown alone and for all purposes). Note the three main areas of production, respectively in Virginia and North Carolina, Georgia and Alabama, and Texas.



tute the major export product of a considerable number of the West African countries and the bulk of the outgoing freight carried on their railroads. It takes the railroad system of Nigeria, which has only a limited capacity, nearly a year to clear the peanut crop of the previous season from the Kano area. Here peanuts awaiting shipment are bagged and stored in huge pyramids, which are prominent on the landscape.

In China peanuts are grown widely and are a major cash crop in the Hwang Ho plains and the Shantung peninsula. The total annual crop of China is estimated at from 2.5 to 3 million tons.

In the southeastern United States peanuts are one of the more important crops. Over half of the total production comes from an area of concentration which extends from the South Carolina border across southern Georgia and most of southern Alabama and which includes parts of northern Florida. Other areas are one in Virginia and North Carolina, immediately west and southwest of Norfolk, and several in Texas. Recent acreages harvested in the United States have have been about 1,500,000 acres with a production of about 900,000 tons (Fig. 136).

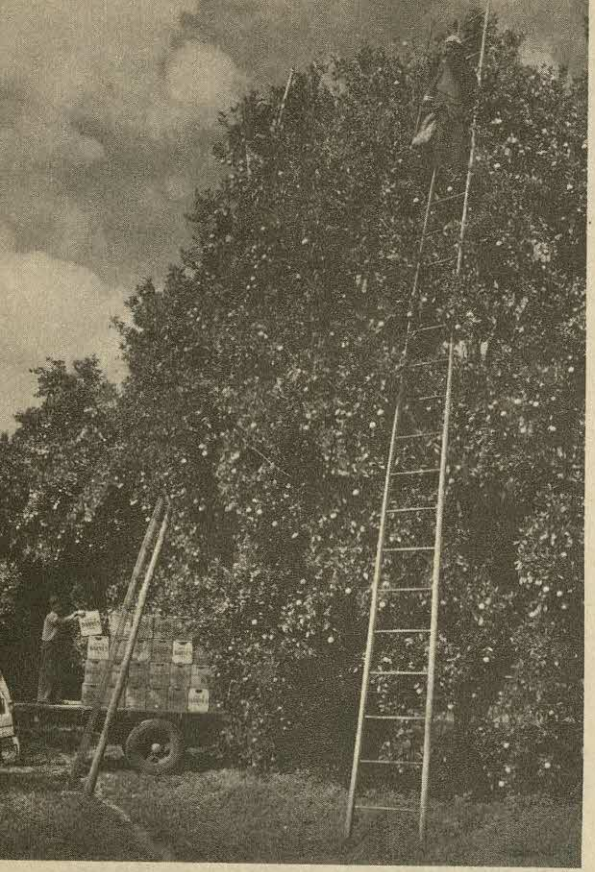
VEGETABLES AND SUBTROPICAL FRUITS

In all regions of humid subtropical climate fruits and vegetables are important for local use. Commercial production, however, has attained a greater development in southeastern United States than elsewhere, because the population centers in the North afford splendid markets easily reached by train and especially by large, cooled or refrigerated trucks over fast modern highways and unhampered by any tariff boundaries. In the coastal lands from Texas to Virginia, horticulture is the leading form of commercial agriculture. The profits from vegetables depend largely upon the possibility of marketing the products before they must meet the competition of those grown near the northern population centers. Growers must, therefore, plant as early in the season as possible and risk the danger of frost. Potatoes from Florida and southern Texas run a close race with those from Puerto Rico in reaching northern winter markets, with slightly later production coming from southern Louisiana, southern Alabama, and the coastal strip of South Carolina. Louisiana and Florida are the leading states in furnishing early strawberries. Southern Florida and southern Texas have developed a large production of early tomatoes, but both, and especially the latter, must compete with Mexican imports. The list of other vegetables grown in this area is long and includes, among others, green beans, carrots, cabbage, early sweet corn, table beets, cucumbers, and spinach.

Tree crops are primarily of the type that cannot be produced in the cold-winter areas. Hence, competition does not result in pressure for early production, except for crops such as Georgia-Carolina peaches.

In central Florida citrus fruit is a major crop. There the severity of the winter cold waves is so modified by the warm ocean water on both sides of the peninsula and by the numerous lakes which dot the surface that large-scale production of the tender subtropical fruits is possible. Citrus fruits are grown also along the Indian River —the long, narrow lagoon between the east coast barrier beaches and the mainland—to beyond Palm Beach. Florida outranks California as an orange-growing state. Favored by an abundance of rainfall, availability of suitable land, and large markets to the north, expansion of acreage is continuing, and so is production of fresh fruit and frozen and canned juice.

Grapefruit. The peninsula of Florida, with humid subtropical climate, and parts of California, Arizona, and the Rio Grande Valley of southern Texas, with an arid climate, are the world's foremost centers of grapefruit production, together accounting for almost three fourths of the world's production (Fig. 137). Other regions with important grapefruit production are Israel, Argentina, and the West Indian islands, especially Trinidad, Jamaica, and Puerto Rico. One of the remarkable developments in recent decades has been the tremendous increase in production and consumption in the United States of fresh grapefruit and



Courtesy Florida Citrus Exchange, Tampa, Florida

Fig. 137. Grapefruit orchard with pickers at work.

canned and frozen grapefruit juice. In 1925 the total production of grapefruit in the United States was 250,000 tons; in 1945 it reached the record figure of 2,500,000 tons. Production has declined to about 1,500,000 tons since. Small quantities are imported into the United States from Puerto Rico, but exports far exceed imports. Most of the exports of fresh grapefruit juice are directed toward Canada. Florida (Fig. 138) will probably remain the principal center of production in the Western Hemisphere because of suitable climate and less danger of loss by hurricane than in the West Indies.

RICE

Although statistical data on world rice production are considerably less reliable than those pertaining to the production of wheat, it appears probable that the total quantities of wheat and rice produced each year do not differ very much. However, as the inedible portion of rough rice exceeds that of threshed wheat, the latter is still the world's major grain. Rice is a major food of the wheatless multitudes of the Far East and southern Asia, and is becoming increasingly important as a basic foodstuff in Caribbean America and parts of South America. In those regions rice is what white bread is to many Europeans, the most desirable, but also a relatively more expensive, food.

It is not known where in the dim past of early human progress rice originated. Wild species of rice are found in the wet swampy regions of southeastern Asia and tropical Africa. The principal species that was domesticated, *Oryza sativa*, has retained all the characteristics that indicate an original swamp habitat. There are numerous varieties of rice, each with its own particular characteristics and requirements, but all must have high temperatures in order to germinate, bloom, and mature. Some of the tropical varieties will not germinate at tem-

Figure 138.

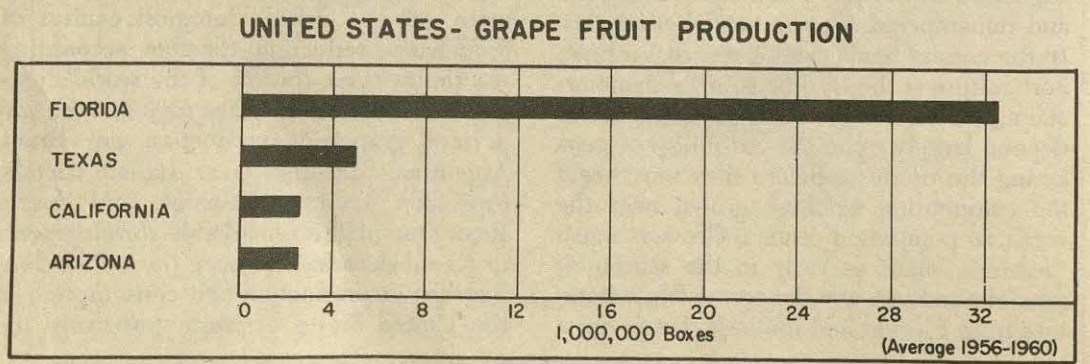




Fig. 139. Plowing the "sawah," or "wet rice field" preparatory to planting rice seedlings from a seed bed. The carabao is the common draft animal in the Orient.

Courtesy "The Lamp," Standard Oil Company of New Jersey

peratures below 68°F., and the most favorable temperature is often considerably higher. Little rice is grown where average January temperatures fall below freezing point.

These temperature requirements make rice primarily a crop of the tropics and subtropics, although small quantities are grown commercially as far north even as the Po Valley of Italy, the Valley of California, and east central Arkansas. Much of the rice of the world is produced in the subtropical areas that extend from Northern Vietnam through China into southern Japan. Thus it is, perhaps, defensible to discuss rice in this chapter, rather than in the chapter dealing with tropical crops.

Within these climatic areas the geographic distribution of the rice crop is limited by its heavy needs for water. It must have much water, both in and upon the soil. The easiest way to supply the water is to irrigate so as to have a shallow layer of water on the land during the entire period of vegetative growth. Unlike most other crops, rice does not require air for germination; therefore it finds a swamp habitat favorable for growth. Thus rice is the only great crop that is grown on actually flooded fields (Fig. 139). Some rice, the so-called upland rice, is grown on dry, nonirrigable land, where it must depend upon precipitation, but this is possible only where rainfall is heavy. Even then yields are meager, and if moisture should be a little below expectations, the crop is often a complete failure. Heavy water-retentive soils, with a high clay and silt content, underlain by a hardpan that slows up percolation, are most advantageous to "padi," or "sawah" (irrigated) rice.

Distribution of production. The climatic and water requirements have tended to limit the cultivation of rice to the great, gently sloping river lowlands, deltas, and coastal plains of tropical and humid subtropical regions, where soils are heavy, temperatures are high, and moisture is plentiful. These factors, together with the demands for food to supply the dense populations, account for the extensive cultivation on the lowlands of southeastern continental Asia, Japan, Taiwan (Formosa), Java, and the Philippine Islands (Fig. 141).

Subsistence agriculture in the tropics, usually primitive and extensive, often even with migratory tendencies, has developed unparalleled intensiveness in those regions

where rice is the principal crop. With primitive implements, but with an unending amount of care and an astonishing quantity of labor, the land is prepared and the rice crop is grown and harvested. The cultivation of rice represents tropical native agriculture at its best and in its most stable form.

Methods of production. With an unlimited expense of labor, the result of generations of effort, the land has been terraced and subdivided into small holdings. Each parcel is surrounded by a little dike to hold the irrigation water, which is admitted or pumped in at the upper side of the terrace system and led slowly from terrace to terrace until the surplus reaches the river below (Fig. 140). The individual rice fields, "paddies," or "sawahs," or whatever their local names may be, are prepared meticulously. They are plowed into a thick, soft mud and carefully leveled. The primitive economy of the native farmer and the small sizes of the fields preclude the use of modern machinery. About the only kind of animal that can stand the rigors of labor and climate is the slow, poorly disciplined carabao, or water buffalo. The young plants, grown with utmost care and attention in nursery beds, are transplanted into the muddy field by hand. Cultivation and harvesting are likewise carried on almost entirely by hand labor (Fig. 139).

The attention given individual plants and the everlasting care for the maintenance of terraces, dikes, and irrigation works make rice cultivation in the Orient one of the most intensive types of agriculture in existence through large use of human labor; in many places it borders on true horticulture. Where the conditions of the natural environment are favorable, especially where an ample supply of water is assured, rice is one of the safest crops that can be grown. With sufficient water, crop failure is rare, although in some lowlands there always

Fig. 140. The famous Banaue rice terraces in the mountains near Baguio, north of Manila, Philippines. Terracing of slopes for rice fields is common in the Orient, but rarely do terraces go quite this far up steep slopes. The terracing was done without the aid of modern engineering.

Courtesy of Embassy of the Philippines and Pan-American World Airways



lurks the danger of destructive floods. In many sections two rice crops can be grown in the course of a year, or one rice crop and one nonirrigated crop. This method of rice production thus makes possible a dense population and at the same time *requires* a dense population because of the amount of hand labor involved. The areas of great rice production are for the most part also areas where the density of population is far above the average.

Rice production is necessarily a stable industry, greatly dependent upon orderly, peaceful conditions, and therefore is likely to develop a highly conservative small peasantry, strongly rooted in the soil. The cooperation and organization that are essential elements in successful rice cultivation undoubtedly aided the early development of such civilizations as those of India and China.

No dietary habit seems to be more strongly entrenched than the eating of rice, and no agricultural habit seems to have become more strongly entrenched than the growing of rice. The peasant of the Indian lowlands, of Java, or of southern China tends to grow rice wherever he goes. This tendency may explain the cultivation of rice in areas which are seemingly on the extreme margin of profitable cultivation, as in northern Honshu, southern Hokkaido, north China, and Manchuria. The preference for rice, coupled with the pressure of population and the absence of adequate transportation facilities, may explain the staggering amount of manual labor expended upon the terracing of hillsides and even of mountain flanks in order to make them fit for irrigated rice.

Western agriculture, which has always centered around the bread grains, has given relatively little attention to rice since in most of Europe the climate is not suitable for the production of rice. It is raised there in only a few favored areas, such as the sheltered plains of Valencia in Spain and the Po Valley in Italy. Here, with the aid of scientific plant breeding and the use of fertilizers, rice yields average over 5,000 pounds per acre in Spain and around 4,500 in Italy. Other average yields are 4,000 to 4,500 in Japan, 4,200 to 4,400 in Egypt, 3,000 to 3,400 in the United States, 2,300 to 2,500 in China, but only 1,200 to 1,300 in India, and even less in most other parts of southern Asia.

The areas where rice could be grown are much larger in North America than in Europe. In many parts of the warm, rainy South the natural environment is favorable; before the Civil War rice was grown with the aid of slave labor as far north as South Carolina. It has not, however, become an important crop in the Southeast because of the minor role it plays in the white man's diet and the amount of and type of disagreeable labor involved in its cultivation. With modern methods adapted to American aims of high production per worker, rice is produced on the low, black coastal prairies of Louisiana and Texas, in the Mississippi lowland of northeastern Arkansas, and in the Sacramento Valley of California. These machine methods have been so successful that at present the United States produces more rice than it needs for home consumption, though rice has become a traditional part of the diet of French Louisiana. Because of the high quality and mass production of the American product, the surplus is exported in successful competition with that grown under primitive oriental conditions. A comparison of rice growing in the Orient and in the United States provides a useful example of the significant differences between oriental agriculture, which aims at largest possible production per unit of land regardless of the amount of human labor involved, and American agriculture, which aims at largest possible production per agricultural worker rather than per land unit. In much of Asia it takes 80 to 100 man-days plus some work from a water buffalo on an acre of rice land to produce 2,000 to 3,000 pounds. In the United States an acre of land may produce somewhat comparable quantities of rice with heavy use of machines and the use of only about seven tenths of a man-day. The reduction in manpower input is brought about by the use of earth-moving equipment for the preparation of the diked fields, by the use of aircraft for seeding the crop, by foregoing

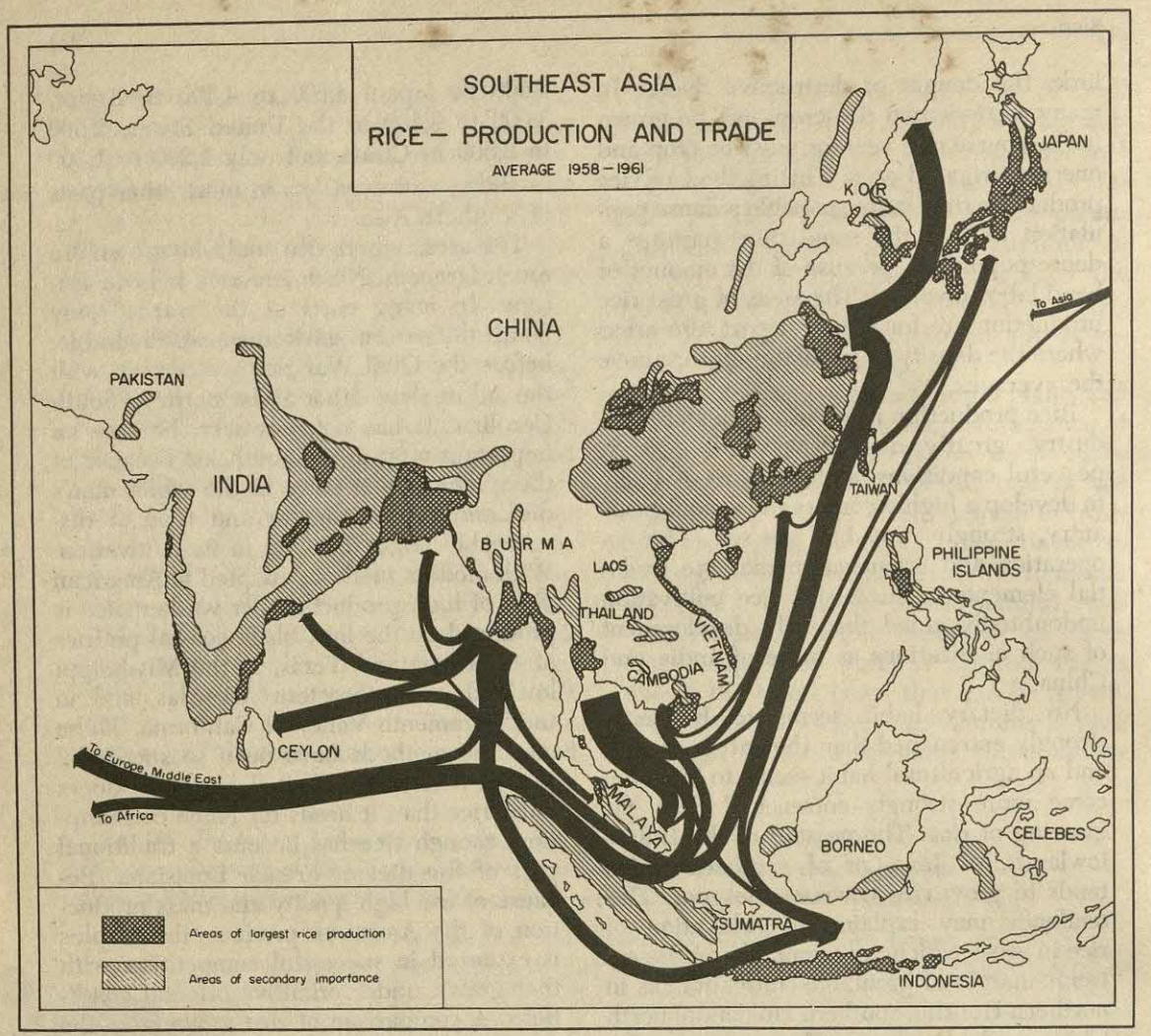


Figure 141.

the transplanting of the rice, and by using combine harvesters for bringing in the rice. Here is one facet of the agricultural revolution in the West. Some adaptations of machine techniques to oriental conditions are possible, and in Japan small, powered plows and cultivators have been introduced with the result of some reduction in the man-day input. However, yields of transplanted rice are highest, and thus it may not be possible in much of the Orient to omit the labor-consuming job of transplanting the rice seedlings.

World production and international trade. Most of the world's rice is grown on small farms for subsistence purposes or for local trade. Only about three per cent of the total production enters world trade. This is in contrast with world wheat production, of which 10 to 15 per cent enters world trade.

Since the mid 1950's the principal rice-exporting nations have been Burma, Thailand, China, and the United States. The regions of surplus production of rice (Fig. 141) are characterized by favorable soil, climatic, and other conditions and (with the exception of China) by moderate to light density of population. The principal importing nations are characterized by high population densities and often by large domestic rice production, which is, however, not sufficient to meet local needs. Among the other importing nations the Philippines

and Malaya could produce sufficient rice for domestic requirements, but the agricultural sector of their economies is directed toward the production of cash crops for export.

India obtains most of its imported rice from Burma; Ceylon, as well as Indonesia, from Burma, Thailand, and occasionally from China; and Japan from Taiwan and Thailand. Burma and Thailand export rice not only to other Far Eastern nations but also to Europe. A large percentage of the rice sold in the East is handled through and distributed by the two great entrepôt ports of Hong Kong and Singapore. Many Europeans countries import rice because their populations were taught its use when early colonial ventures made it available at comparatively low prices. While only a small percentage of the world's rice crop is produced in Europe and North America, the quality of the rice is high, as is the yield per acre. Some of these nations have rice available for export. The United States is the principal rice exporter of the Western world and commonly ranks third or fourth among all rice exporters. Rice from the United States is exported mainly to India, Indonesia, Pakistan, and West Germany, with smaller amounts going to other nations of Europe and Africa. Italy, Spain, and Hungary have modest exports.

Some rice is consumed as flour and as starch. A small milling industry has developed in several Western countries, especially in those which are rice exporters.

TEA

The tea shrub (*Thea sinensis*) is a broad-leaved evergreen limited in commercial production to areas where there is no cold season. It is, however, tolerant of a wide range of warmth such as prevails in the tropical and subtropical regions. The tea bush has been known to survive as far north as southern France, and it can be grown in southeastern United States.

As the tea shrub is moisture loving, its commercial cultivation is confined to rainy tropical and humid subtropical regions. The teas of commerce consist of the dried young leaves and tender sprouts of the shrub, and the necessary vigorous growth is possible only where rainfall is ample and dependable and the air constantly humid.

The tea industry requires an abundant supply of cheap labor. Plucking and preparing the leaves is a tedious task, and one that requires considerable skill. It is improbable that any kind of machine can ever be devised to perform this work. Successful tea plantations can therefore be established only where density of population is high and labor costs relatively low. These environmental and economic factors are responsible for the concentration of the commercial tea industry of the world in the countries of southern and eastern Asia. Minor centers of production are located elsewhere, such as in the humid subtropical portion of Transcaucasia in the Soviet Union (Fig. 142).

Historical development. The necessity for extreme caution with drinking water and the practice of boiling it may be partly responsible for the early popularity of tea among the Chinese. From the Far East the use of tea spread to Europe and other parts of the world. From a luxury which only the rich could afford, it became a necessity and an important article of world trade. At present, production of tea for the world market is concentrated in certain sections of India and Pakistan, Ceylon, Indonesia, China, and Japan (Fig. 143). There is increasing production in eastern Africa, notably in Nyasaland, Kenya, and Mozambique.

There are two main varietal groups of the tea plant, the Chinese and the Assam. The latter was discovered wild by the British in northeastern India and has been domesticated. It grows taller and has much larger leaves than has the Chinese variety. While China and Japan grow the Chinese varieties exclusively, India, Ceylon, and Indonesia cultivate the Assam tea.

Distribution and commercial production. India is the principal tea exporter of the world. The industry centers in the flat, alluvial lands on either side of the Brahmaputra river and in the region immediately south of the Assam Hills. This part of the



Courtesy Indian Tea Cess Committee

Fig. 142. Picking time on a tea estate in upper Assam, India. The tea bushes are kept pruned low for easy picking of the young leaves.

country has very high rainfall, averaging from 80 to 100 inches per year in the tea regions proper. High humidity, heavy dews, and morning fogs favor rapid development of young leaves. From December to February, however, this part of India has a cool season, at which time the shrubs remain dormant. During the remaining nine months leaves can be picked every eight or nine days. A small tea area lies in the foothills of the Himalayas, near Darjeeling, where the tea gardens are at altitudes of up to 4,000 feet. Here the slow growth of the plant, resulting from lower temperatures, leads to the production of a high-grade leaf. The yield per acre, however, is considerably less than in the lowlands. In southern India tea is grown along the rainy west flanks of the Western Ghats. There, and in neighboring Ceylon, plantations lie at greater altitudes than in Assam. No unfavorable season interferes with the growth of the leaves, and picking can continue throughout the year.

Tea is grown in all sections of Java, but production is most intensive on the fertile volcanic soils of the higher districts of western Java, where rainfall is plentiful at all seasons. The Deli district on the east coast of Sumatra has also become a producing area.

The tea produced in India and Indonesia is of the black type, which requires fermentation of the leaf, along with withering, rolling, and firing. The Assam variety contains a high percentage of tannic acid (tannin), and although the fermentation process eliminates nearly half of this, sufficient is left to impart to the beverage a strong flavor and a certain pungency liked by Western consumers.

Chinese tea, grown principally in China, Japan, and Taiwan, is more delicate than the Assam variety. It is made into both green and black tea. Green tea is that which is not allowed to ferment. In China production centers in the hilly belts that surround the Yangtze basins. The summer monsoon brings considerable precipitation to all of southern China, and this, together with high temperatures, favors the growth of young leaves. In most districts there are three harvests: one in the early spring (March-April), furnishing first-quality leaves, the so-called *Pekoe;* the second in the early summer (May, June), yielding leaves of

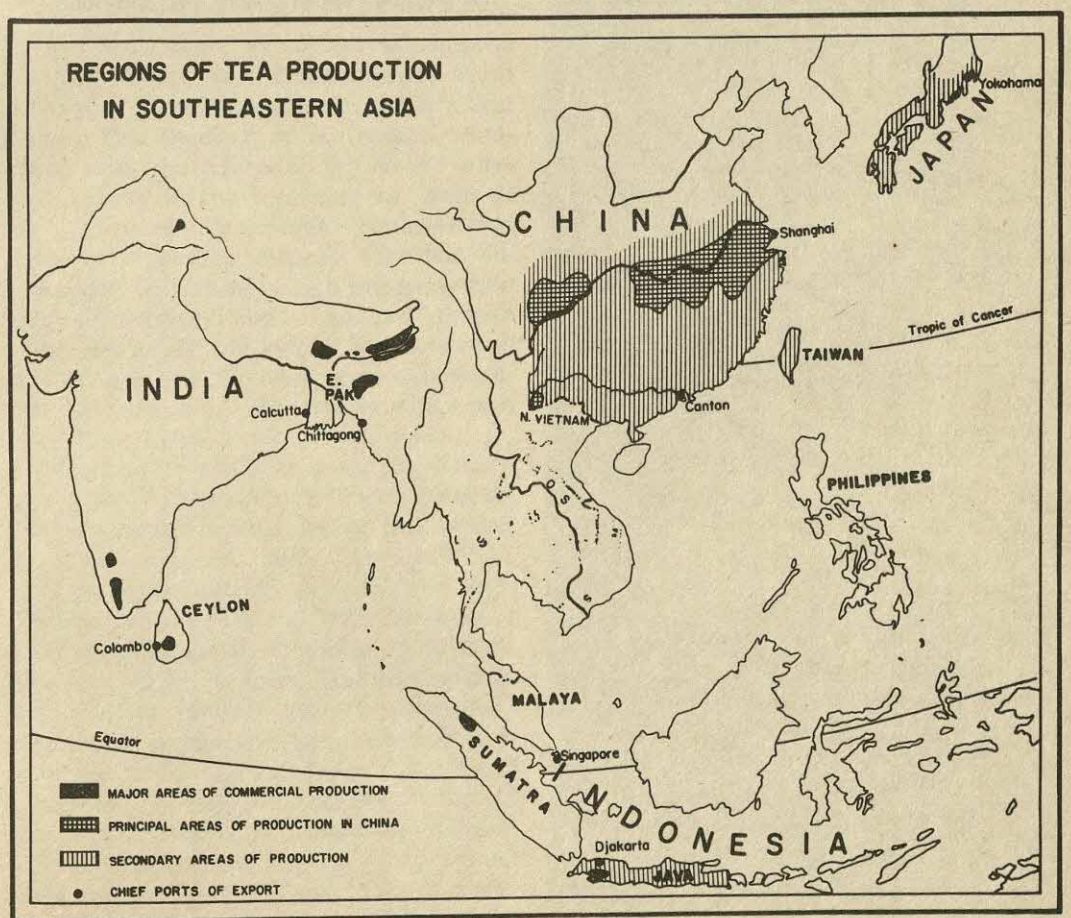
medium quality; and the third in late summer (August, September), yielding leaves of decidedly inferior quality, which do not enter world trade.

Production has been in the hands of small farmers who devote most of their time to the cultivation of foodstuffs and grow tea as a spare-time crop, chiefly on sloping lands not suitable for other crops. The large number of miniature tea gardens and the nearly complete absence of modern plantations have resulted in a heterogeneous product not so suitable for large-scale commercial methods of selling. Furthermore, the methods of manufacture are rather antiquated. As late as the end of the nineteenth century China was the world's most important exporter of tea, but exports have declined greatly as a result of the competition of other areas which grow teas of stronger flavor.

In Japan tea production centers on the Pacific side of southern Honshu, Shikoku, and Kyushu. This part of Japan has milder winters and receives considerably more rain from the summer monsoon than does the west coast. The growing season lasts from six to eight months and, as in China, three to four pickings are possible. Much of the tea is grown in the foothills and on higher terraces, where there is less competition from other crops. The exports consist entirely of green teas. Taiwan is well-known for its production of *oolong*, a semifermented tea.

Tea is traditionally an English drink.

Figure 143.



More than three fifths of the tea that enters world trade is exported to various parts of the British Commonwealth. It is therefore logical that the principal tea-trading center of the world should be located in London, in the well-known Mincing Lane district. The only other country with a high per capita consumption is the Netherlands. Although Russia is the land of the samovar, tea has remained a relatively expensive product, notwithstanding some domestic production south of the Caucasus Mountains. Most of the tea imported into the United States originates in India, Ceylon, and Japan. Minor quantities are imported from Indonesia, Taiwan, and China.

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13

The Intermediate Climatic Regions—I

characteristics of the humid types

BETWEEN THE belts of all-year warm climates and the all-year cold are belts marked by vigorous seasonal extremes, the areas of the prevailing westerlies or of the cyclonic storms, where we find the intermediate climates.

In the Southern Hemisphere the belt lies mostly over water, between the southern parts of the American, African, and Australian continents and the Antarctic continent. Only southern Chile, southern Argentina, Tasmania, and New Zealand are affected all year long by this belt. In the Northern Hemisphere the major land masses of North America and Eurasia are located within it. Meteorologically and climatologically the northern belt is far better known than the southern belt, and it is also of much greater importance. Thus, most of what is said here applies to the Northern Hemisphere.

In the regions of humid intermediate climates atmospheric circulation is complex. Cold air masses from the north meet warm air masses from the south in cold or warm fronts. This meeting of air masses, combined with the effects of the earth's rotation, results in the formation of large or small areas of low pressure—*cyclones* that move in a general west-east direction—interspersed with areas of high pressure—*anticyclones*—which have a similar, though often less rapid, movement. The low-pressure areas move with an average velocity of from 30 to 35 miles per hour in winter and from 20 to 25 miles per hour in summer.

Fronts and cyclones are most pronounced and move farthest south in winter, invading the subtropical regions during this period. In North America, *polar continental air masses*—which are cold and relatively dry—develop in the north and from there move southward, especially in winter. *Polar maritime air*, which is moist and cool and in winter even rather warm in comparison with polar continental air, is formed over the area of the Aleutian Low. This type of air greatly affects the northwest coast of North America, but it is modified considerably when it moves over the Rocky Mountains and becomes not only drier but also warmer.

Tropical maritime air masses are formed particularly in the subtropical latitudes over the oceans. These air masses are warm and moist and reach North America mostly from the Gulf of Mexico and the Atlantic Ocean. Similar air masses from the Pacific affect the American climate only to a relatively small extent. *Tropical continental air masses* are also of relatively small importance, as the only source for such air masses is northern Mexico, which is an insufficiently extensive land mass. Very warm and dry air of this type is formed in summer only and is important in accounting for summer drought in southwestern United States. Thus, much of North America where the major portion of the people live is affected primarily by polar continental air masses and tropical maritime air masses. On the whole, continental air masses dominate the climate and thus, even immediately along the east coast, the American climate is continental rather than marine.

In Europe the opposite is true: as west winds predominate, the major invading air masses come from the ocean and consist of either polar maritime air or tropical maritime air. The former type, especially when arriving from the west to southwest, has been warmed so much by moving for long distances over water that it brings moderate winter conditions to Europe. Tropical maritime air is cooled to some extent by its long route over the ocean, but it also contributes to the generally mild winters of Western Europe.

Polar continental air forms in the northeast, especially in winter, over the vast snow-covered land masses of northern Russia. Thus cold winter weather in Europe comes from the northeast rather than from the northwest, as it does in the United States. Tropical continental air does not play much of a role in the area of intermediate climates of Europe.

There are two major groups of climatic types within this belt: the humid and the dry. The humid climates have rainfall sufficient to promote a native flora of forest or tall grass; the dry climates have an annual rainfall commonly less than 20 inches, and the native vegetation is of the steppe type, consisting of either short grass or scattered bush. In this chapter only the humid intermediate climates are considered. The humid intermediate climates are most typically developed in North America and Eurasia. In the Southern Hemisphere the middle latitudes are chiefly oceanic; the land masses are mostly tropical or polar. The occurrence of winter snowfall and the absence of a dry season are characteristic of all subdivisions of this climatic type, but the intensity and duration of winter cold and snow differ greatly. Principal contrast is between the continental interiors and the west coastal areas. The interiors of North America and Eurasia experience long, snowy, intensely cold winters, increasing in severity poleward, though summers are warm and sunny. Owing to the eastward drift of the air masses in these latitudes, the continental climate extends to the east coasts, although it is slightly modified there by the proximity of the ocean. The west coasts, on the other hand, are dominated by air masses moving in from over the ocean, resulting in comparatively mild winters and cool summers. Snow, if it falls, does not generally stay on the ground very long, except in mountain areas.

The humid intermediate climates can thus conveniently be discussed under four subdivisions: (1) the *humid continental climate* of central and eastern Europe, northern China and Japan, central and eastern United States (see World Map of Climatic Regions, No. 8); (2) the *east coast continental climate,* which is typical for part of the east coast of the United States and for part of Japan (see Map, No. 9, and Fig. 144); (3) the *west coast marine climate,* developed in western North America from Oregon to Alaska and extending over a considerable area in western Europe (see World Map of Climatic Regions, No. 10, and Fig. 144); and (4) the *subpolar climate,* which dominates much of Canada, Sweden, Finland, and northern Russia (Map, No. 11).

All these types have rainfall sufficient to develop native vegetation of forest or tall grass and to support crop farming, where other conditions permit. The seasons are

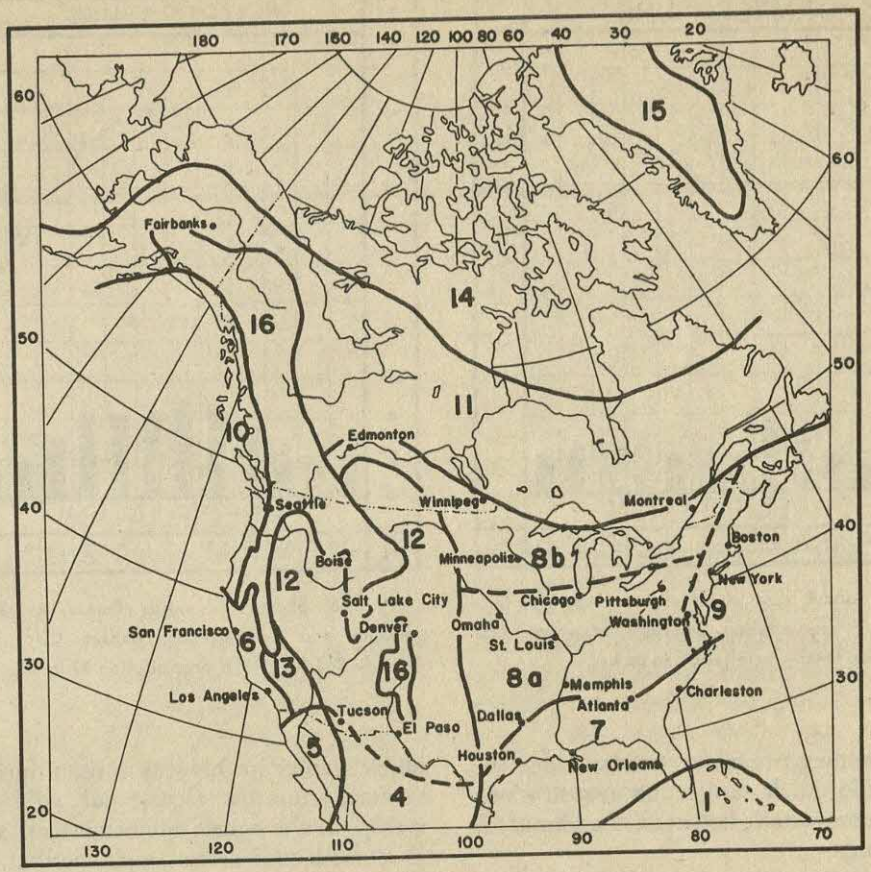


Fig. 144. Climatic Types in North America.

Legend:

1. Tropical Rainy Type
4. Tropical Steppe Type (includes subtropical type)
5. Warm Desert Type
6. Mediterranean Type
7. Humid Subtropical Type
8. Humid Continental Type
9. East Coast Continental Type
10. West Coast Marine Type
11. Subpolar Type
12. Middle Latitude Steppe Type
13. Middle Latitude Desert Type
14. Tundra Type
15. Ice-cap Type
16. Mountain Climate Type

based on changes in temperature rather than on seasonal changes in the amount of rainfall. All have climatic conditions that appear to stimulate mental and physical activity.

THE HUMID CONTINENTAL CLIMATE

The humid continental type of climate is limited to North America and Eurasia. In the United States this type of climate reaches from the subtropical South to southern Canada. In Europe it predominates in southeastern Europe and Russia west of the Urals. In the Far East it is encountered in northern China, Korea, and Manchuria.

Temperature. The average temperature of the coldest month is below 42°F., but not more than four months have averages that drop below freezing. The average temperature of the warmest month is at least 36 degrees higher than that of the coldest month; often the difference is even greater (Figs. 145, 146 and 147, 148). This large annual range generally does not cause serious discomfort, although summer heat waves can be more enervating than the

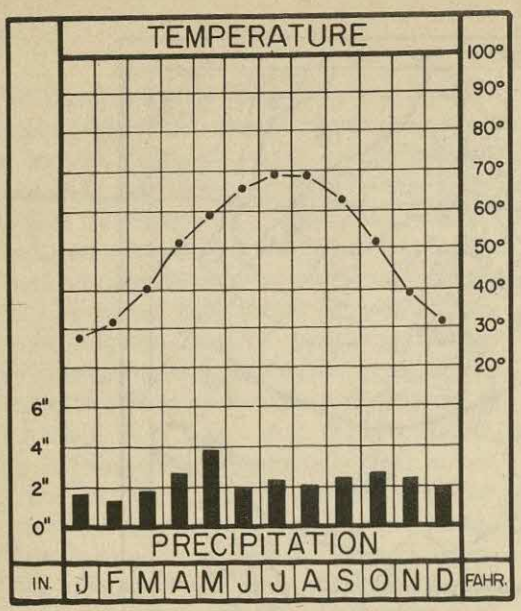


Fig. 145. Short, cold winter climate. Average temperature and precipitation, Budapest, Hungary. Altitude 411 feet, total precipitation 26 inches.

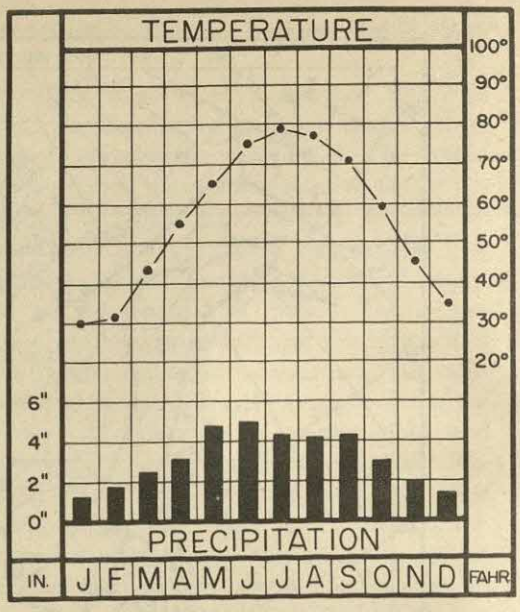


Fig. 146. Short, cold winter climate. Average temperature and precipitation, Kansas City, Missouri. Altitude 963 feet, total precipitation 37 inches.

heat in many parts of the tropics, since the sun rises so much earlier and sets so much later. On the whole, however, the climate is stimulating.

The growing season varies in length from about 100 to 240 days. Light frosts may occur during the early and late weeks of this period, but ordinarily they are not injurious to the major crops. In the southern sections the winters are mild, but along the northern borders subzero weather is likely to occur during the coldest months. Toward the north the long, cold winters preclude the production of slow-maturing crops and the growing of fall-sown grains. Throughout most areas periods of cool to moderately cold weather are likely to be interrupted by severe cold spells each winter. The areas most remote from the sea are characterized by periods of severe cold in winter and intense, sometimes devastating heat in summer.

Winds and storms. In North America and Europe these areas are dominated by the cyclonic storm conditions of the prevailing westerlies.

The cyclonic storms are strongest in winter, and their paths then lie farthest south. As a result, fluctuations of temperature are much greater in this season than during the summer months. Occasional cold waves sweep down across the American Middle West with such stormy violence that locally they are referred to as *blizzards*. On such occasions mild, balmy weather may give way suddenly to zero temperatures, a blinding snowfall, and piercing winds. During pioneer times people were often caught entirely unprepared, and personal suffering and serious losses of livestock resulted from these storms. With the development of weather warnings broadcast by radio, some of the danger can be avoided. Farmers and ranchers, thus forewarned, are usually able to provide feed and shelter for the stock while the storm rages. However, upon occasions, such as during the winter of 1948-49, blizzards of great intensity and duration occur, which still cause severe losses.

During the winter eastern Europe is under the direct influence of a large area of high pressure over the interior of Asia, which forces the lows coming in from the Atlantic Ocean to take a northeasterly course. These moving lows bring sharp changes of temperature to the Russian plains, often veritable cold waves and blizzards, there called *burans*. Occasionally the

Asiatic high-pressure area becomes so pronounced that it extends far westward into European Russia, or even farther west. At such times prolonged periods of dry, clear, and cold weather may occur. In eastern Asia the monsoons dominate the weather, while cyclonic wind movements play a minor role. The high-pressure area of eastern Siberia causes strong outblowing winds in winter, while in summer the pronounced low-pressure area gives rise to persistent inblowing winds. (See Figs. 57 and 58.)

In summer the most feared weather phenomena, especially in the American Plains west of the Mississippi, are the hot winds. Occasionally low-pressure areas centering in the upper Mississippi Valley move so slowly that they appear to be almost stagnant. Then southerly winds continue for days over the plains from Texas to the Dakotas, bringing with them soaring temperatures. When the land is dry, temperatures often exceed 100°F., occasionally surpassing 110°F., with blasting effects upon growing crops and serious damage to trees and grass. The summers of 1934 and 1936 were examples of the extremely serious effects of such winds when attended by continuous drought. In those years the corn crop of the United States fell to about half the normal.

During spring and early summer, when air conditions are unstable owing to the change from cold to warm season, small, violently whirling air masses occasionally develop. These whirls, known as *tornadoes,* are among the most destructive storms known. Within some tornadoes such wind velocities are reached that few structures are able to withstand their attacks. Fortunately, the path of maximum destructiveness is not often more than half a mile wide.

Precipitation. The average annual rainfall varies from about 20 inches in the drier areas to 50 inches in the more rainy sections. In general, the amount of rainfall varies inversely with distance from the sea. Summer maxima of rainfall are prevalent nearly everywhere, but decidedly dry winters are typical only of northern China and of the American interior west of the Mississippi. The well-developed summer maxima are

Fig. 147. Long, cold winter climate. Average temperature and precipitation, Moscow, Russia. Altitude 492 feet, total precipitation 24 inches.

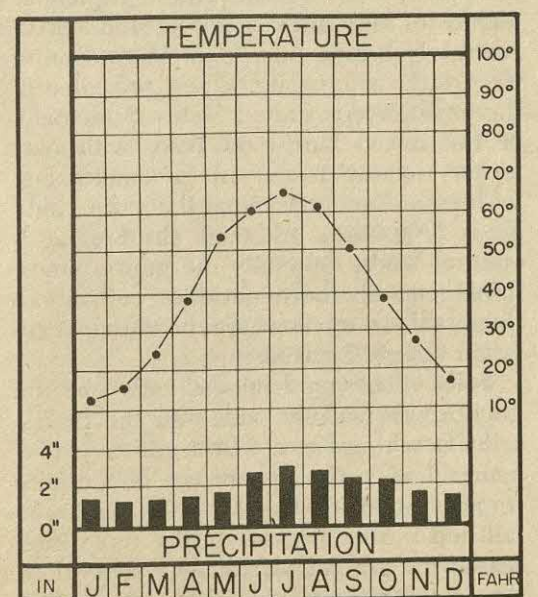
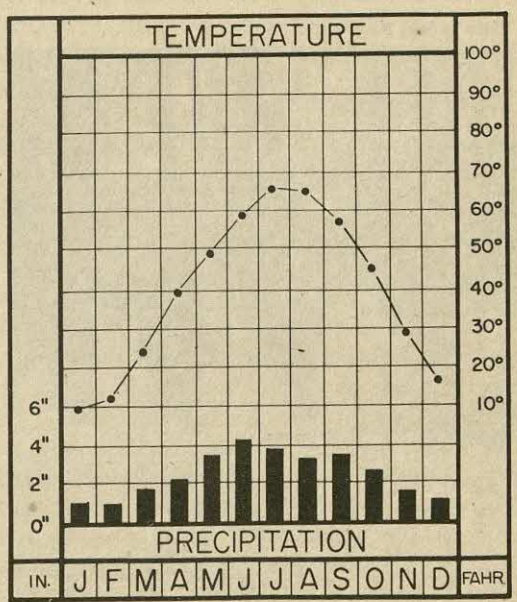


Fig. 148. Long, cold winter climate. Average temperature and precipitation, Duluth, Minnesota. Altitude 1,133 feet, total precipitation 29 inches.



very important in accounting for the successful crop agriculture of interior areas where the annual rainfall is only 20 to 35 inches; 65 to 75 per cent of it falls during the growing season. Toward the seaboard the annual precipitation is greater, and the seasonal distribution is more uniform. In the north the efficiency of rainfall is higher because of the lower summer temperatures and the briefness of the warm season.

In the comparatively dry areas where this type of climate adjoins the areas with intermediate steppe climate, such as in the American Plains and in Russia, variability of rainfall is great. This is particularly important because the effects of high variability are much more pronounced here than in more humid areas. Sometimes several years in succession may have rainfall so far above normal that streams overflow, wet-weather ponds become all-year lakes, and lowlands are flooded for such long periods that crops are damaged or even ruined. Then many people, convinced that a great change in climate has occurred, start agitating for drainage projects. Under the impulse of such misguided notions many miles of unneeded drainage ditches have been constructed at great expense. Later on, when dry years come, as they inevitably do (either singly or several in succession), crop failures and pessimism go hand in hand. Many then believe that a permanent drought has set in and that the country is destined to become a desert waste. Instead of drainage, the construction of dams to impound water for irrigation purposes becomes the popular cry. In each situation, whether flood or drought, the popular mind is likely to be stirred by the immediate outlook rather than quieted by the facts of long-term records. Weather records and other evidence show that dry or wet years, or series of years, have come and gone in the past and doubtless will continue to come and go. In these dry regions economic activities, agricultural and industrial, should be organized and operated in such a manner that the effects of fluctuating rainfall are taken into account.

Fig. 149. Deciduous forest of mixed hardwoods, northern Wisconsin.

Photo by N.A.B.



Native vegetation. The original vegetation of the areas with this type of climate consists principally of deciduous forest in the more humid sections and tall-grass prairie in the areas of lower rainfall. In China and Europe the land has been under cultivation so long that, except in the rougher mountain areas, little of the native vegetation remains. In the United States the prairie was originally the conspicuous feature of the landscape from Indiana to central Nebraska and from Minnesota to the Ozarks of Missouri. Forest prevailed in the northeastern United States, principally of the mixed hardwood type, with oak, hickory, chestnut, and ash predominating, with pine stand on some of the more sandy lands (Fig. 149). Although the best agricultural lands, especially the prairie lands, have generally been put into cultivation, there still are tracts where the native vegetation covers the landscape.

Soils. The predominant soils are the gray-brown podzolic soils and the prairie soils. Leaching has not been quite so pronounced as in the soils of the humid subtropics, partly because of lower annual rainfall and partly because during the winter season the ground is frozen for some time, thus making the water in the soil inactive.

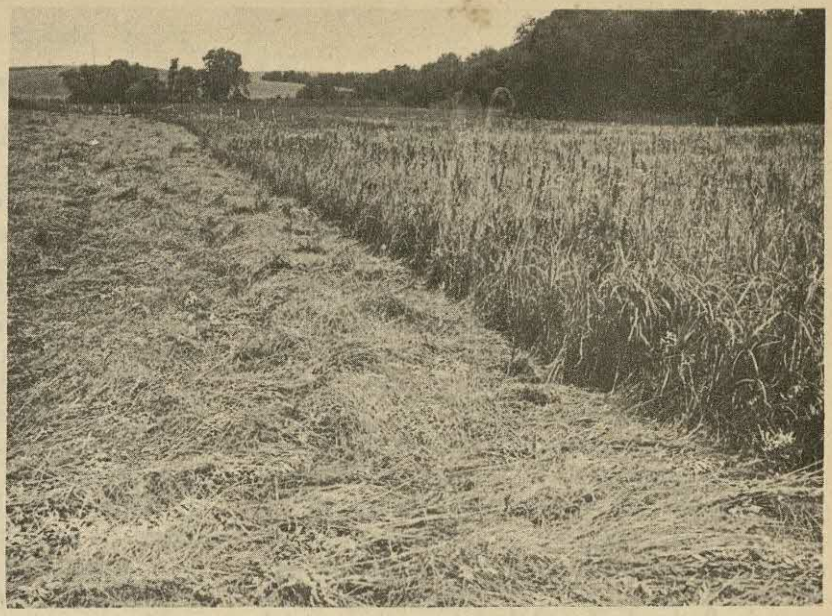


Fig. 150. The tall-grass prairie of eastern Nebraska, in the region of dark prairie soil. Native flora now occurs in strips not farmed along roads.

Photo by N.A.B.

The lower annual temperatures, and particularly the seasonal cold, account for less effective oxidation than in warmer climates, and therefore the soils are brown rather than red.

In the United States this climatic region includes vast areas of plains where the soils have been developed from rocks of high lime content and where their structure still shows the beneficial influence of the former presence of lime, even though leaching has removed most or all of the calcareous elements from the upper horizon. Such are the mature upland soils from central Ohio to central Iowa. These "calcific" types are characterized by a stable structure that enables them to remain in good physical condition under cultivation.

In the areas where tall grass rather than forest prevails, deep, dark, friable soils occur. These are known as prairie soils because they have developed under grass cover; their A horizons are deep and dark brown in color, owing mainly to the high content of organic matter. Although the prairie soils are classified as pedalfers, because they are nonlime accumulating, they are but slightly leached and so are productive with little use of fertilizers. These soils are dominant from Illinois to eastern Nebraska and eastern Kansas, and they include some of the best farmlands in the United States (Fig. 150).

In the eastern and southern portions of this climatic region in the United States, where winters are generally mild and the rainfall is fairly heavy (40 inches or more), the soils are more thoroughly leached, and the color is brown or gray-brown. The structure is quite stable; in fact, the strong physical constitution of the soils is their greatest asset. Fertilizers are effective and hence need not be used in such large quantities as where weaker, less responsive soils are found. Still farther south in this climatic region, for example, in southern Missouri, Tennessee, and Virginia, we find the red and yellow soils of the South becoming dominant.

In the northern section of the region in North America, extending from northern Minnesota through northern Wisconsin, northern Michigan, and the adjacent portion of Canada to the Adirondacks, leached gray soils, known as podzols, are predominant. These soils also occupy much of the northern parts of this climatic area in Russia. The name is an old Russian folk term which has long been applied to these gray soils; it is derived from the words *pod*, or soil, and *sola*, meaning ash. The podzols are acid soils, deficient in minerals and well-decayed organic matter. The surface layer of the true podzols consists of raw, insufficiently decayed humus material, derived from needles of conifers, mosses, twigs, and

leaves, and may reach a thickness of a foot or more. This layer really lies *on* the surface. The upper soil, the real A horizon which lies underneath this, is gray to white in color and highly leached of plant nutrients and sesquioxides, iron and aluminum compounds. The structure is simple, either platy or granular. The B horizon, or subsoil, is dark brown in color and compact, owing to precipitation of organic matter and the iron and aluminum compounds leached from the upper soil. This type of extremely leached soil fortunately is limited to the northernmost parts of the area under discussion. Farther south the brown soils mentioned previously in this chapter are not so badly leached, and the humus they contain is well decayed: they are *podzolic* soils, but not true podzols.

With only lime added, the more highly podzolized soils, if virgin, often yield fairly well for two or three years because of the plant nutrients found in the capping humus layer. This, however, is soon exhausted, and then heavy applications of mineral fertilizers are necessary to maintain productivity.

On the whole, the regions of humid continental climates are favored with soils of high agricultural potentialities. Although the soils are mostly pedalfers, neither leaching nor oxidation has been excessive, soil structures are quite stable, and the organic content is comparatively high. On most of the mature soils, particularly on the various types of gray-brown podzolic soils and on the podzols, manure and mineral fertilizers are needed. In the United States the quantities used west of the Appalachians as yet are not great (Fig. 341), but they are increasing steadily. Since the soils of this area are responsive to fertilizers, moderate amounts will suffice to maintain fertility. In fact, in this country many of these soils, though theoretically outranked in fertility by the pedocalic soils farther west, actually are of considerably higher productivity because of a more favorable rainfall regime.

General aspects of land utilization. Wide diversity of crops is characteristic of regions with this type of climate. In Eurasia corn is of major importance only in some of the Danubian countries and southwestern Ukraine, whereas in the United States it is a major crop. In northern China, wheat, millet, and beans are the principal subsistence crops of a dense population. There, with the use of simple, almost primitive equipment, agriculture is carried on by hand-labor methods. Production per capita is low, but all available land is fully used in order to support the masses of people dependent directly upon it, and the total production is large. Pressure of population upon the land is so great that little surplus can be produced. As a result, the peasants have few or no reserves, and famine is frequent.

In Europe wheat, rye, corn, root crops, and hay constitute the basis of a successful agriculture carried on largely by modern methods but with machines of small size and simple design, compared with the larger and more complex equipment used on the more extensive farms of the New World.

In the United States corn is king in a large part of this region (climatic type 8-a, Fig. 144). From an American point of view, this area of comparatively short (in comparison with 8-b) and cold winters, and fairly long and hot summers may well be called the Corn Belt climate, because the area extending from Ohio to eastern Nebraska and from southern Minnesota to the Missouri Ozarks is by all odds the greatest corn-producing region in the world. However, it is not a one-crop region. The farmers raise not only corn but also large quantities of soy beans, oats, wheat, root crops, and forage, particularly legumes, and they are large producers of livestock as well. South of the Corn Belt proper lies a zone of transition from the humid intermediate to the humid subtropical climate, which is also a transition zone from corn to cotton as major crops. There soft winter wheat is so important that it runs corn a close race for first place. Within this transition zone are located the famous tobacco-producing areas of Virginia, North Carolina, and Kentucky, the greatest tobacco-growing districts of the United States. North of the Corn Belt proper (climatic type 8-b) the transition to the long winter type of climate is marked by a

gradual increase in the importance of oats, soft spring wheat, root crops, fodder crops, and dairying.

In the northern portions of this climatic area crop production of cereals is limited almost entirely to those which can mature in a short season. Flax, barley, and spring wheat are the typical grain crops. Flax, grown only for seed in North America, is produced also for fiber in Russia. Sufficient moisture during the earliest period of growth, large accumulated temperatures during the long days of the short growing season, and warm, dry weather during the harvest season are factors favorable for the production of wheat and barley of excellent quality. Rye is the fall-sown grain. Corn is grown chiefly for silage or fodder because of the danger that it will not reach maturity. Some legumes, especially clover, and tame grasses are important fodder crops. Root crops do especially well in this climate. In regions where little or no corn is raised, potatoes not only are a staple food for people but also are used extensively as food for livestock. Some districts are important for sugar beets. The yield per acre is generally less than where the summers are long, but this is offset by the higher sugar content which results from the long periods of daily sunlight in summer.

THE EAST COAST CONTINENTAL CLIMATE

Along the east coasts of North America and Asia between 35° and 50°N. latitude, the humid continental climate is somewhat modified by proximity to the ocean. It is well developed in North America from New Jersey to Newfoundland and along the Asiatic coast from central Honshu northward (World Map of Climatic Regions and Fig. 144).

Temperature. Average temperatures are about the same as those in the corresponding latitudes of the continental interiors, but seasonal extremes are more moderate. For example, Eastport, Maine, has an average January temperature of 21°F. and an average July temperature of 60°F. St. Paul, Minnesota, in about the same latitude, has an average 9 degrees lower in January, while its July average is 12 degrees higher than that of Eastport. Spring arrives later in east coast climatic regions than in the interior, the last killing frost usually occurring two or three weeks later. Autumn is also retarded, but usually not so much as the spring.

The seasonal range, though smaller than that in the interior, still exceeds considerably that of the west coast marine areas. The annual average temperature at Portland, Maine (46°F.) is only 6 degrees lower than that at Portland, Oregon, in approximately the same latitude, but the January average is 17 degrees lower, and the July average is one degree higher. Thus, on the leeward coasts the summers are about as warm but the winters are much colder than those on windward coasts in higher middle latitudes.

Winds. When winds are from the east they bring to New England and maritime Canada quantities of damp air from the ocean which give rise to periods of piercingly chilly weather in winter. In summer the winds from the ocean are cool and pleasant along the shore, but, because of their high moisture content, they tend to become oppressive and enervating farther inland where land temperatures are higher. New York and Washington, D.C., have a number of notoriously uncomfortable, hot, humid days every summer.

Rainfall and humidity. The precipitation, which generally amounts to 40 to 80 inches annually, is distributed quite evenly throughout the year. The amount of precipitation is particularly noticeable in the winter snows; in New England the snowfall may exceed 80 inches in a single season, with much of it remaining on the ground for three or four months. Northwestern Japan, too, has heavy winter snows. In Japan, however, there are sharp contrasts between the east and west coasts. The west coast of Honshu receives its maximum precipitation in early winter as a result of the winter monsoon from over the Sea of Japan, while the east coast has heaviest precipitation during the summer monsoon, with September being the rainiest month.

Vegetation. The native vegetation characteristic of this type of climate resembles that of the adjacent, more continental climates. In America, deciduous forests—consisting either of an oak and poplar association or, farther north, of an association of birch, beech, and maple—are prevalent on lower and better lands (Fig. 151). Pines are concentrated on the sandier soils, while at higher elevation spruce and fir appear. Where forests have not been cleared, logging and lumbering are important. Another activity of economic importance in New England and New Brunswick is the gathering of maple sap and the manufacture of maple sugar and syrup.

In northern Japan, deciduous forests prevail—beech, maple, and oak being the principal trees. The many different kinds of maple are especially responsible for the beautiful autumn landscape for which Japan is justly famous. In the mountains coniferous forests are dominant.

Soils. In the lower and warmer sections, from the coastal area of Maine to Maryland, brown and gray-brown podzolic soils are the most common mature soils, while in the New England uplands and adjacent parts of Canada, podzols predominate. Alluvial soils provide the basis for the limited but successful agriculture practiced in the latter regions. In Japan, gray-brown soils prevail in the south and podzols in northernmost Honshu and Hokkaido.

Land utilization. The use of the land is influenced to a great extent by the relatively low temperatures which prevail in many areas. Coolness and cloudiness are handicaps to the complete maturing of certain crops, in the northern sections especially. In general, the summers are too cool for corn to mature, although some of the finest green corn for human use (sugar corn from Maine) is grown in this climate. Corn is produced also for fodder and silage. In the northern part of this climatic region wheat will not ripen satisfactorily, but oats and rye, both of which are well adapted to cool and humid environments, are produced successfully. Potatoes, vegetables, and fruits are important in subsistence agriculture, and where physical conditions are favorable and markets are available they may become major cash crops. Aroostook County, Maine, for example, is famous for its potato production. Cranberries are grown in such abundance that Massachusetts and New Jersey furnish the nation with about 70 per cent of its supplies. The ample precipitation, including winter snows, and the lack of extreme summer heat and winter cold favor the successful apple orcharding of New England and Nova Scotia. Most farms have woodlands on their poorer portions (Fig. 151).

The east coast humid continental climate has sufficient changes of temperature to be bracing and invigorating. It has fewer ex-



Fig. 151. Farm scene in New Hampshire, near Pittsfield. Typical New England stone fence in foreground, constructed of glacial boulders. Dairy farm in middle ground; woods on the higher hills.

Courtesy U.S. Department of Agriculture

tremes of summer and winter than have the continental interiors, but there is enough change to avoid tiresome monotony of weather.

THE WEST COAST MARINE TYPE OF CLIMATE

Two areas in the Northern Hemisphere have a well-developed marine climate: the west coast of North America, from San Francisco to Alaska, and northwestern Europe, from Portugal to Norway (see World Map of Climatic Regions and Fig. 144). In the Southern Hemisphere this type of climate occurs in Chile, from Puerto Montt to Cape Horn, and in New Zealand. Of course, conditions vary considerably through such a wide range of latitude, but moderate temperatures and abundant rainfall, well distributed but with an autumn maximum, prevail throughout. Where lofty mountains occur near the coast—as in North America, Chile, and Norway—the marine conditions are strikingly developed in the narrow regions along the coast and on the lower mountain slopes. In Europe, south of Norway, the lack of a high mountain barrier permits the oceanic influence to be carried far inland, but with diminishing intensity. Naturally the rainfall is heavier, and seasonal temperature extremes are less on the windward slopes than on the leeward slopes of low mountain ranges, such as the Pennines of England.

Temperature. The significant feature of this climate is the small range of temperature during the year, owing to the tempering influence of the westerly winds blowing from over the oceans. The difference between the average temperatures of the warmest and coldest months ranges from 18 to 36 Fahrenheit degrees (Fig. 152). Winter and summer are, of course, warmer in the lower latitudes than farther poleward at places equally near the coast. At Lisbon, for example, the average temperature of the warmest month is 70°F., of the coldest, 49°; at Copenhagen, 62° and 31°; at Bergen, 58° and 34°. Mild winter temperatures extend surprisingly far poleward in this climate. Even far beyond the Arctic Circle in Norway the winters are so mild that the coastal waters remain unfrozen throughout the long winter months.

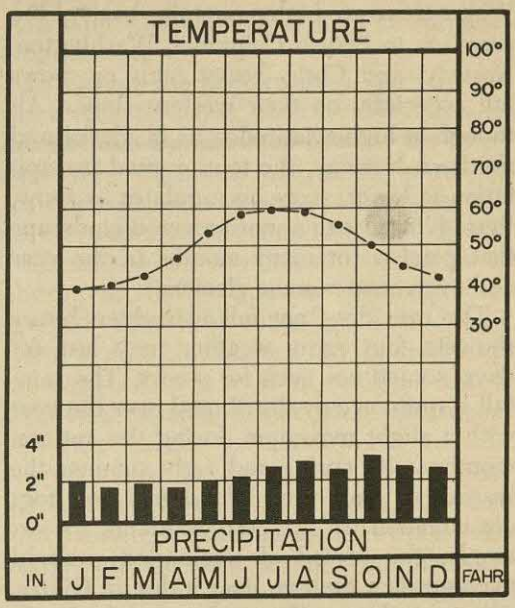


Fig. 152. Marine west coast climate. Average temperature and precipitation, Liverpool, England. Altitude 99 feet, total precipitation 28 inches.

Winds. The weather is dominated entirely by the numerous masses of maritime air that move in from the sea, associated with low-pressure areas. The passing of these lows causes constant shifts of wind direction and wind strength, resulting in highly variable weather. Nevertheless, winds from westerly direction are by far the most frequent—from the southwest during the winter months, and from the west and northwest during the summer. The stormiest conditions prevail along the west coasts of Scotland, Norway, and southern Chile; the latter faces the highly developed westerlies of the Southern Hemisphere known as the "roaring forties."

The southwest and west winds bear the tempering influence of the sea across France and Germany into Poland and even Russia, though with increasing distance their effects become less pronounced.

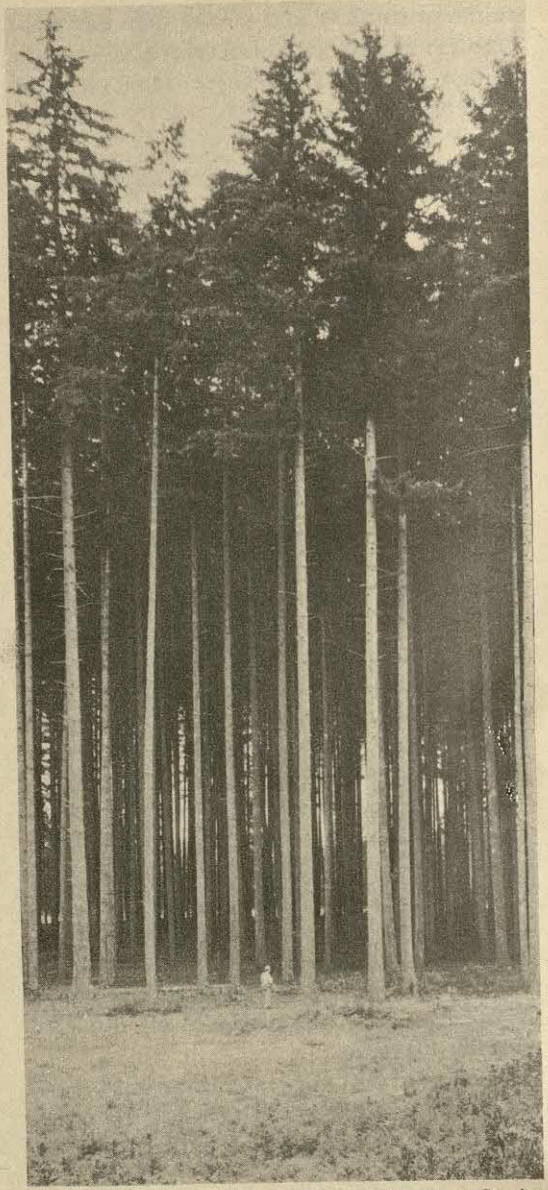
Rainfall. The amount of rainfall varies with local conditions and with latitudes.

Where there are high mountains back of the coast—as in British Columbia, Washington, Norway, and Chile—heavy rains or snows fall especially on their western slopes. Although at higher latitudes, as in Alaska and northern Norway, the total annual precipitation is lower, more accumulates as snow, thus giving rise to a snow-covered landscape that persists for many months of the year and even creates some glaciers.

The rain does not fall in sudden heavy showers, but rainy weather may last for days, sometimes even for weeks. The rainfall is quite evenly distributed over the year with a slight maximum during the autumn months, with spring and early summer the seasons of least rain. Cloudiness and fogs are common. In northern Scotland, for example, the period of unclouded sunlight averages less than an hour a day in winter. All of northwest Europe has much cloudy and rainy weather, especially in the fall and early winter. Sometimes the sun may not be seen for weeks, and umbrellas, raincoats, and overshoes are always needed. These typically marine conditions of prevalent cloudiness and autumn rainfall maximum change with distance from the ocean. Eastern France, Germany, and southern Sweden have a slight maximum in summer and clearer skies than the British Isles or Brittany.

The high humidity causes the winter cold to be sharp and piercing, even when the thermometer may stand well above the freezing point. In summer it often causes extremely muggy weather; then temperatures of 80°F. may cause quite as much discomfort as those of 100° in the Great Plains of the United States.

Native vegetation. The mild west coast climatic regions have or have had heavy forest covers. Dense stands of timber, mostly firs, characterize the western mountain slopes from California to Alaska, one of the most heavily wooded regions in the middle latitudes and at present one of the world's principal centers of lumbering (Fig. 153). The southern Chilean coast, where not too rocky or too boggy, likewise has heavy stands of timber, as yet little exploited. With the exception of parts of the British Isles, where the strong west winds hamper tree growth and the high precipitation favors the development of moors, most of northwest Europe once was heavily forested with deciduous hardwoods and conifers. However, the lands suitable for agriculture were cleared long ago and put into grass or tillage. In England but little forest remains, and on the continent forests are limited



Courtesy U.S. Forest Service

Fig. 153. Farm forest of Douglas fir in Oregon.

mostly to the mountains and to very sandy areas. None of them are original stands. Southern Norway has extensive stands of spruce and fir, but the northern part has few trees, because of long seasons with land temperatures below freezing.

Soils. In the mountainous areas along the coasts of North America, Chile, and Norway, agricultural soils are limited to the valley lands. Only a small percentage of the total area is arable. These lands, which are wholly alluvial, vary much in different localities, but the gray-brown podzolic soil types seem to be most common. The soils are young, and where drainage is adequate and texture favorable to cultivation they are usually quite fertile.

Northwestern Europe is the only region of marine climate where a large percentage of the land is used for tillage agriculture. The mature soils are predominantly gray-brown podzolic soils, with well-developed podzols on some of the sandier lands. The structures of the former are fairly stable, and crop yields are readily increased by the application of mineral fertilizers. Among the best soils are those developed upon the alluvial deposits of the valleys and upon the recent marine deposits along the coasts, as in the Netherlands and parts of southern Sweden. Glacial deposits mantle much of the land which borders the North Sea, with soils varying in productiveness from the nearly sterile sands of parts of northern Germany to the fertile loams of eastern England and the Danish islands. Farther south, nonglacial soils occur, varying in quality from medium to good. On the whole, however, the soils of northwest Europe are favorable to agricultural development, although heavy application of fertilizer is necessary.

Land utilization. In North America and Chile the forest is the principal asset of the regions which have the west coast marine type of climate. The valley lands of the Pacific Northwest are important centers for grazing, dairying, and truck farming. The principal agricultural region here is the Puget Sound-Willamette lowland. Vancouver, Seattle, Tacoma, Portland, and smaller cities mark urban districts which give rise to profitable markets, especially for bulky or perishable products that cannot be shipped long distances.

In Europe the region with a marine west coast climate shows considerable climatic diversity. In the south all seasons are comparatively warm and mild; in the north all seasons are cool, so cool that only the hardiest crops survive. In Scandinavia the change from marine to continental conditions is abrupt; in the lowlands of Germany it is gradual. The west coasts of Ireland and Great Britain are cloudy and rain drenched; the east coasts have more sunshine and a moderate rainfall. Under these conditions it is little wonder that agricultural diversity is pronounced. In southwestern France vineyards abound, while in Norway only hay and hardy crops such as rye and barley can be grown. Because of high rainfall, oats is the principal grain in the western and northern parts of the British Isles, while wheat leads in eastern England and in France. Potatoes constitute an important phase of crop agriculture in many parts of this region, especially in the Netherlands and Germany, the latter usually ranking foremost among all countries in amounts raised. Poland, also, although not wholly within this type of climate, is a great potato-producing country. The abundance of natural grasses and root crops, as well as the large markets furnished by the industrial centers within this region, favor the development of the dairy industry. The renown of the Netherlands and Denmark as dairy countries rests upon the secure basis of a favorable natural environment, skillful operation by intelligent and industrious farmers, and proximity of markets which insure profitable outlets for the products.

Viewed as a whole, regions with the west coast marine type of climate are lands of forest wealth, agricultural diversity, and industrial achievement. Climatic conditions are sufficiently varied to be stimulating, but not so extreme as to be enervating.

THE SUBPOLAR TYPE OF CLIMATE

Poleward from the other intermediate climates lies a belt of transition that practi-

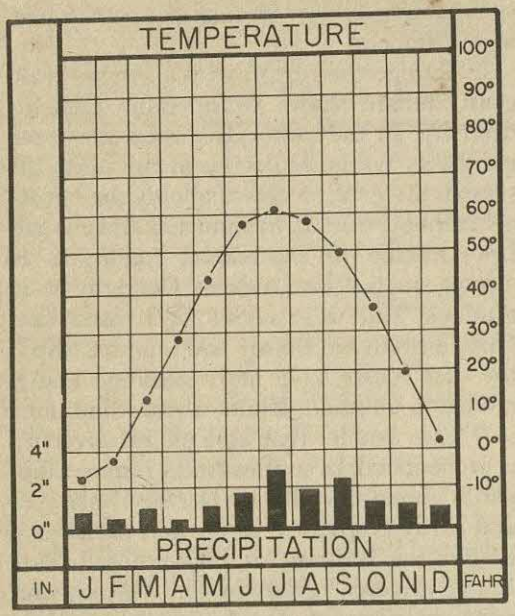


Fig. 154. Subpolar climate. Annual temperature and precipitation, Fort Hope, northern Ontario, Canada. Altitude 1,100 feet, total precipitation 16 inches.

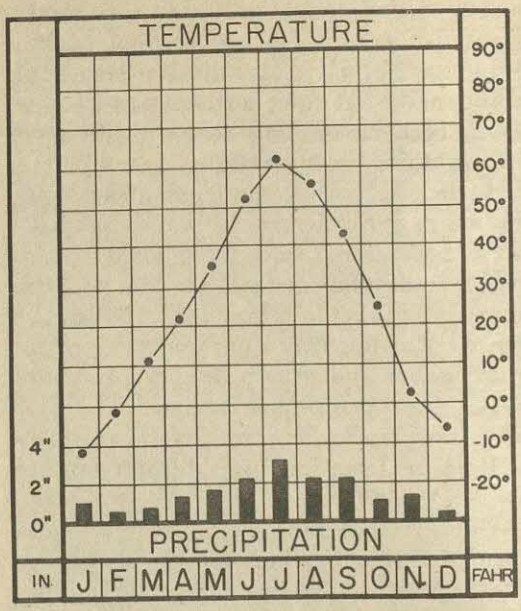


Fig. 155. Subpolar climate. Annual temperature and precipitation, Beresov, Siberia. Altitude 100 feet, total precipitation 18 inches.

cally coincides with the great belt of northern coniferous forests which girdles the Northern Hemisphere. The subpolar type of climate dominates northern Sweden and Finland, northern European Russia, most of Siberia, central Alaska, and much of Canada. Within this belt a winter landscape of somber dark green and cold, dreary white is predominant for nearly nine months of the year. During a brief summer period of nearly continuous daylight, nature bursts into life with grasses and multicolored flowers which carpet the ground wherever the forest is not too dense to exclude them. Trees put forth new leaves. Insects and birds appear in swarming numbers, enlivening the short summer season by their hum and song and busy activities.

Temperature. While climatic conditions vary considerably within the subpolar regions, the long, intensely cold winter is common to all. Average temperatures of 50°F. or above are reached less than four months each year, and even in the warmest season light frost may occur at night, although day temperatures may be favorable for plant growth. The native vegetation, therefore, consists of plants that are tolerant of the cold and able to utilize a short and rather unsafe growing period. Crops must be hardy and ripen quickly; in the far north barley is the only grain crop that gives satisfactory yields. The soil and subsoil are free of frost during the midsummer period, a factor of great importance to the development of the forests that prevail over most of the subpolar climatic regions. The high annual range of temperature is another marked characteristic (Figs. 154 and 155); the hottest summer days may exceed 90°F., whereas in the dead of winter the temperature may drop to −60°F. or even lower.

Winds and storms. The regions of subpolar climate lie along the northern margin of the belt of prevailing westerlies. Cyclonic storms reach these regions in summer, particularly central Canada, northern Russia, and western Siberia. In winter masses of cold continental air often originate here and spread outward. At all seasons weather is subject to sharp, sudden changes. While in most places travel is easiest in winter, be-



Fig. 156. White spruce forest in a river valley in Alaska. Photo taken from Mile 134, Glen Highway.

Courtesy U.S. Forest Service

cause the bogs and rivers are then frozen and the land is snow covered, severe gales and accompanying low temperatures often bring hazards.

Continentality of climatic conditions reaches its climax in Siberia, east of the Yenisei river. Pressure is abnormally high there during the winter, atmospheric disturbances are infrequent, and the air is calm; as a result, temperatures often fall below the freezing point of mercury, −39°F., but the dryness of the air and the absence of strong winds contribute toward making such temperatures bearable. A distinct disadvantage, however, is the lightness of the snow cover, or its absence. Summer temperatures, on the other hand, may be surprisingly high. At Verkhoyansk, the "cold pole of the earth," summer temperatures of above 90°F. have been registered. In central Canada temperature extremes are not as great as in Siberia.

Humidity and precipitation. The precipitation is comparatively light, with a distinct summer maximum. Few places have an average of more than 20 inches per year. Because of the low temperatures which prevail most of the time, the relative humidity is fairly high and the rate of evaporation is low. The summer rains and the melting winter snows supply sufficient water for the vegetation which flourishes through the short season. Where the growing period is less than three months long, precipitation of 15 inches is ample, whereas in lower latitudes semiarid conditions would result. The winter snowfall, even when light, ordinarily accumulates so that for several months each year the landscape is blanketed with white, without interruption by warm spells which produce the well-known thaws of more southern climes.

Native vegetation. The regions of subpolar climates coincide roughly with the great belt of the northern coniferous forests, known as *taiga* in the USSR. Spruce, fir, and larch are the dominant species. Only a few of the hardiest deciduous trees, such as birches, poplars, and willows, are found. Growth is slow because of the very short period wherein sunlight, warm air, and soil combine to favor plant growth. Tree roots commonly are shallow.

Over the southerly portions of these regions in Canada and Eurasia, forest is continuous and fairly heavy (Fig. 156). In its undisturbed condition, much of the taiga forms a dense jungle of standing and fallen trees often covered with mosses. Toward the northern border the forest becomes scattered and scraggly as it approaches the limit of tree growth. Where local conditions are relatively favorable, a prong of forest projects northward; where they are unfavorable, only shrubs or a mixture of shrubs and stunted trees survive. It is the margin of the coniferous forest where neither tree nor

moss can claim supremacy. North of it is the treeless tundra.

Soils. The soils are podzolic. A forest litter covers the upper horizon, and under it lies the well-known very light gray layer leached of its soluble minerals and organic matter. The soils are, however, of subordinate importance, as climatic conditions make it very difficult to carry on successful agriculture, especially of the commercial type. The agriculturally important soils are limited almost entirely to the immature alluvial lands bordering streams and lakes.

Land utilization. On the whole, in the regions of subpolar climates man has not made great inroads upon the natural landscape. Such agriculture as is practiced is distinctly of the patch type and is almost wholly for local subsistence purposes. Barley, of the hardiest kind, is the chief cereal grown, although some rye is produced in a few districts along the southern margin. Potatoes do quite well and serve as an important foodstuff in some areas, particularly northern Sweden, Finland, and Russia. Hardy vegetables and quick-maturing berries play a local role.

The forest is the principal resource. It has not yet been widely exploited in North America because other forested areas are closer to markets, but with their depletion will come increasing demands upon the resources farther north. In Norway and Sweden exploitation is carried on profitably, coupled with a replanting program that has won wide acclaim. Russia has vast forest resources within the subpolar climatic region. While improvements have been made in the exploitation of these forests, many parts of the Russian forest belt are handicapped by poor transportation facilities and by the fact that the major streams flow northward, toward the Arctic Sea.

The northern coniferous forest to date has

Fig. 157. In the northern forests there are many swampy areas, where the tree growth is sparse or absent, and where timber usually is of little or no commercial value. "Muskeg" in Tongas National Forest, southeastern Alaska.

Courtesy U.S. Forest Service



been of less economic importance for its trees than for its furs. The fur-bearing animals of Canada, Alaska, and Siberia have long provided the essential raw materials for the world's finest fur coats and scarfs. The activities of hunting, trapping, trading, and transportation serve as the basis of existence for some of the oldest and best-known corporations in the world, among which the Hudson's Bay Company is conceded prime position in North America.

On the whole, the subpolar regions are characterized by such climatic hardships that they must be classified as unfavorable to human progress. They contain resources of great importance, but exploitation awaits demands from without these regions. Their fur resources have long been exploited successfully, but markets have been and are now almost entirely where climatic conditions are less severe. The forests will become increasingly important as sources of pulpwood and structural timber for the lands to the south. Exploitation of mineral wealth, however, is economically feasible if the mineral is of sufficient value and the deposit of high quality and sufficient size to warrant the necessary investment. In Sweden, Finland, and Russia the southern portions of this belt have been developed to a greater degree than elsewhere.

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14

The Intermediate Climatic Regions—II

characteristics of the semiarid and arid types

In the middle latitudes, dominated by the prevailing westerlies, the dry lands are found only east of high mountain ranges or far inland where cyclonic storms are weak and infrequent. The former is the case in North and South America, the latter in Eurasia east of the Black Sea. These dry intermediate climates may be divided into two main types: the semiarid, or steppe, and the arid, or desert type.

The middle-latitude steppes and deserts generally have greater annual range of temperature than the neighboring regions of humid climates; summers are hotter, and winters colder. The diurnal range also is relatively great; the days are warmer and nights colder than in the humid regions, and the passing of occasional lows may bring sudden and violent changes in temperature.

In general, the average annual rainfall in the semiarid intermediate regions is below 20 inches, and that of the deserts is less than 10 inches. Inasmuch as average annual temperatures are considerably lower than in the dry tropical regions, evaporation is less rapid, and whatever precipitation falls is more effective. Therefore, less rainfall is required here to make a climate humid than is true in the hotter areas.

Although in the semiarid lands trees are generally lacking, except along the larger watercourses, the rainfall is sufficient to maintain a fairly continuous vegetative cover consisting of short grass and xerophytic bush, which can support grazing. Where rainfall is greatest, some of the land can be used successfully for crop agriculture. None of the deserts, except the Takla Makan of Chinese Turkestan, exhibits conditions of such extreme aridity as are found in the Atacama or in the Sahara. However, vegetation is so sparse that the carrying capacity of the land is very low, and it can be used only for extensive nomadic herding.

THE INTERMEDIATE SEMIARID TYPE OF CLIMATE

The most extensive semiarid regions in North America (Fig. 144) are: (1) the Columbia Plateau, lying between the northern Rockies and the Cascades, and (2) the

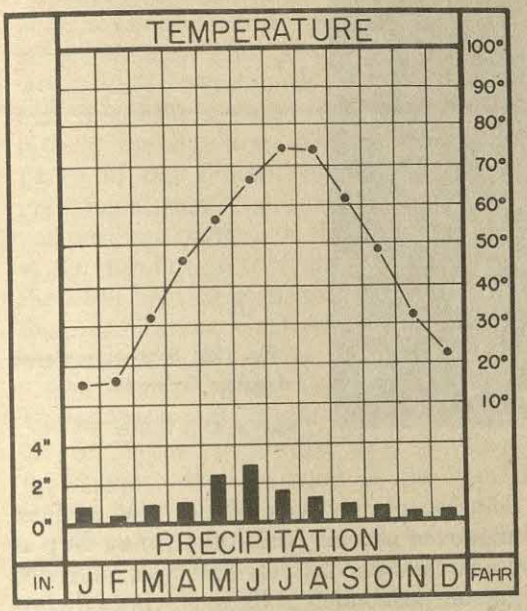


Fig. 158. Middle latitude steppe climate. Average temperature and precipitation, Miles City, Montana. Altitude 2365 feet, total precipitation 13.5 inches.

Great Plains, extending from southern Texas well into Canada along the eastern front of the Rocky Mountains. Still more extensive are the steppes that extend from southern Russia far into the interior of Asia. The corresponding region of steppes in the Southern Hemisphere lies along the eastern base of the Andes in Argentina and in southeastern Australia (see World Map of Climatic Regions).

Temperature. Temperature conditions vary widely with latitude and altitude. The average summer temperatures, June to August inclusive, vary from 80°F. in Texas to 60°F. in southern Canada, while the winter temperatures, December to February inclusive, vary from 50°F. in Texas to 10° or 15°F. in southern Canada. The average length of the frost-free season is not less than eight months in the warmest portions, while in the colder areas it is but three to four months (Fig. 158).

Winds. Although these semiarid regions lie in the belt of the prevailing westerlies, local weather conditions vary widely. In North America the westerlies bring moderate rainfall to the Columbia Plateau during the winter season, but east of the Rocky Mountains the moving areas of low pressure induce little precipitation until after they have crossed the Great Plains. In late spring and early summer, when the storm paths are farther north than in winter, humid marine tropical air masses from the Gulf of Mexico may penetrate far inland and bring to the Great Plains the major share of their annual rainfall, partly in the form of thunderstorm precipitation.

In southern Russia and Siberia, cold northeasterly winds from the Asiatic high-pressure area prevail in winter, while in summer the winds generally are from a northwesterly direction. During both seasons the effects of cyclonic storms passing to the northwest are occasionally felt. In the interior of Asia between the Pamirs in the west and the Great Khingan Mountains in the east, a distance of well over 2,000 miles, the climate is dry (from semiarid to arid) as a result of remoteness from the sea and the existence of high mountain walls, such as the Himalayas and Tibetan mountains and plateaus to the south. The summer monsoon of eastern Asia is able to penetrate only into the southeastern portions of this area, giving rise to a belt of steppe country over 100 miles wide. Also farther to the north, in Mongolia, where the land is higher and the summer temperatures more moderate, there are extensive grass steppes. Here still lie the ruins of Karakorum, the capital of Genghis Khan's nomad empire during the latter part of the twelfth century.

Wind velocities are relatively high across the unobstructed surfaces of most semiarid plains. In the northern Great Plains of the United States and Canada blizzards occur during the winter season: strong, cold winds accompanied by very fine, blinding snow. Severe blizzards cause heavy losses of domestic livestock and wild animals. During the summer season, on the other hand, hot winds are not uncommon, particularly in the lower latitudes along the eastern margin of the Great Plains. Protracted periods of drought and high temperatures cause such winds to be destructive to farm crops, and



Fig. 159. Short-grass steppe of eastern Colorado.

Photo by E. J. Weaver

in some cases to the natural vegetation as well.

Humidity and rainfall. Although the average annual precipitation of most semiarid climates varies from about 10 to 20 inches, these limits are by no means exact. In the middle latitudes the semiarid regions of both the Americas have a wide extent north and south. Hence, differences in temperature, length of the growing season, and rate of evaporation, as well as rainfall, affect the degree of aridity. In southwestern Texas, for example, evaporation during the long warm season is about twice as great as in the shorter, cooler warm season of the northern part of the Great Plains. Consequently, areas in Texas with more than 20 inches of rainfall may be semiarid, whereas those in the north may be classed as humid with even less than 20 inches.

In North America crops of the cooler areas, in addition to being favored by a lower rate of evaporation, have the advantage of a highly favorable seasonal distribution of rainfall. This is particularly true of the Great Plains. At Calgary, Canada, 73 per cent of the annual rainfall occurs during the months from May to September. On the Columbia Plateau 50 per cent of the annual rainfall may be expected from November to February inclusive. The former climate strongly favors spring wheat; the latter, winter wheat.

Variability of rainfall is perhaps the most critical climatic factor in semiarid regions. Some years may have 50 per cent or more above the normal, while others may drop as much below. Such variability is of much greater economic significance where the average is near the lower limit of tolerance for crop plants than where the average is relatively high. There seems to be a tendency for comparatively wet and dry years to occur in groups, but without any dependable regularity. Furthermore, in the Great Plains particularly, rainfall is below the statistical average in more than half the years. In the same place the rainfall may range from an amount sufficient to maintain humid agriculture to one hardly able to support scattered bush vegetation. This variability should be considered normal for most of the semiarid lands of the world. Agricultural and pastoral activities should be planned and practiced accordingly. During wet years preparation should be made for the drier years that will follow. There is no evidence at present to indicate that any permanent climatic changes are now occurring.

Native vegetation. The regions of intermediate semiarid climates are characterized by comparative sparseness of vegetation, but the vegetative cover is practically continuous and thus contrasts with that of deserts where vegetation occurs in patches or may be entirely absent. There are four major types of vegetation formations, all of them of the low-growing type; trees are found only along watercourses.

In the more humid sections, where the

rainfall is sufficient to cause relatively deep penetration of moisture, grasses of medium height abound. This type of semitall grass vegetation is transitional between the subhumid and the semiarid climatic areas, and thus is found within both. In the Great Plains of the United States, the semitall-grass vegetation occurs in both the eastern and northern portions, in the former because of a somewhat greater rainfall total, and in the latter because of the greater efficiency of the precipitation, which results from a lower evaporation rate.

The semitall-grass vegetation of the United States and Canada merges westward, and in Russia southward, into the short-grass type which to many is the typical steppe (Fig. 159).

Where the rainfall is too low to support much grass, and where temperatures are relatively cool, sagebrush is likely to predominate. This type of natural vegetation prevails in the drier sections of Montana and Wyoming as well as on the Columbia Plateau, where it is dominant over large areas.

In the southern part of the Great Plains, in New Mexico and southern Texas, mesquite and thorny bush interspersed with some grassy areas are typical.

Soils. The mature soils of semiarid regions are pedocals. They are dark in color and have a zone of alkaline salt accumulation, usually, although not exclusively, of lime carbonate. The color is generally dark brown in the more humid sections and lighter brown where rainfall is lower. Furthermore, they are darker colored in the cooler portions than they are in warmer areas.

The soils of the eastern Great Plains of North America are black soils, located in the transition belt from humid to semiarid climatic conditions. They correspond to the chernozems which developed under similar climatic conditions in the steppes of European and Asiatic Russia. They are darker than the true semiarid soils, and the zone of lime accumulation occurs at greater depths, usually from two to three feet below the surface. The dark-colored horizon is 10 to 24 inches thick and has a stable granular structure. The black soils are among the aristocrats of soils, initially productive without the use of fertilizers, rich in humus, and readily tilled. Given a sufficiency of moisture, they will yield abundantly for many years. However, owing to the climatic conditions, long-range average crop yields on these soils are generally appreciably below those on the prairie soils and on many of the gray-brown podzolic soils (Fig. 160).

Where rainfall is less than in the chernozem areas, the soils are lighter in color and shallower, and the lime accumulation zone is nearer the surface. On the basis of their color, these soils have been classified as chestnut and brown soils. They have been developed under a grass cover which, because of lower rainfall, was of lighter growth and had a shallower root system than the grasses which originally dominated in the black-soil areas. The lime accumulation zone occurs from six to eight inches to two feet below the surface.

In areas approaching desert conditions, where rainfall is too low to support continuous grass cover, the soils belong to a group known as the sierozems and gray desert soils. These are the principal soils in the Great Basin and Colorado Plateau regions of the United States. The color varies from light brownish gray in the north to almost reddish in the south. The surface horizon is a thin, pebbly layer, and under it is a zone of light, porous material. The subsoil is usually brown and compact. The zone of lime accumulation is near the surface and is often firmly cemented into a mineral hardpan, referred to as *caliche* in western United States. The gray desert soils are necessarily low in humus because of the paucity of vegetation which can be supported by the meager rainfall.

On the whole, the soils of the semiarid lands are readily tilled and are productive where water is available. Crops yield abundantly under irrigation, or without irrigation in years when rainfall is above normal. The unleached soils contain an abundance of soluble mineral salts. Since under natural conditions these salts are usually well disseminated throughout the soil, they do not impair productivity. However, when irriga-

tion water is applied, care must be taken to provide adequate drainage or the alkali salts will become concentrated near the surface of the soil by the evaporation of excess moisture. Such concentration causes good lands to become "alkaline" and thus almost worthless for crop production. Costly errors involving disastrous consequences have been made in some of the irrigation projects by failure to recognize the danger of concentration of alkali salts.

Land utilization. Semiarid lands nearly everywhere mark the transition from crop farming to cattle along their humid margins and from cattle to sheep in their drier portions. During wet periods, crop farming may become so profitable that it encroaches seriously upon grazing lands, only to be forced to retreat again upon the inevitable return of dry years.

The semiarid regions are important in wheat production, autumn-sown varieties, called winter wheat, being dominant in the warmer sections and spring wheat in the areas where the winters are severe. The semiarid lands of Russia, Canada, and the United States include some of the greatest wheat-producing regions of the world. The wheat lands are located in the more humid portions of the steppe, where the accumulated winter moisture is augmented by sufficient spring and early summer rainfall to make a wheat crop before the heat and summer drought become severe. The best wheat lands are in the chernozem areas, where the sufficiency of moisture was early indicated by the taller grasses. Wheat is also produced in the drier areas of chestnut brown and brown soils, but yields are less dependable, and such lands are therefore more definitely marginal than are the chernozem districts (Fig. 160).

The wheat crops which ordinarily place Kansas, North Dakota, Montana, Oklahoma, and Nebraska at the head of the procession in the United States are produced chiefly in the more humid portions of the Great Plains.

Cattle grazing is important in all semiarid regions, the intensity depending upon vegetation and marketing facilities. Forage crops are produced to supplement the natural pasture wherever pressure of population is such that the land can profitably be used to nearly its full capacity. Drought-tolerant forage crops, such as millets and sorghums, have been brought from Eurasia and introduced into the southern Great Plains with conspicuous success. The open range which formerly characterized the semiarid lands of the United States has given place generally

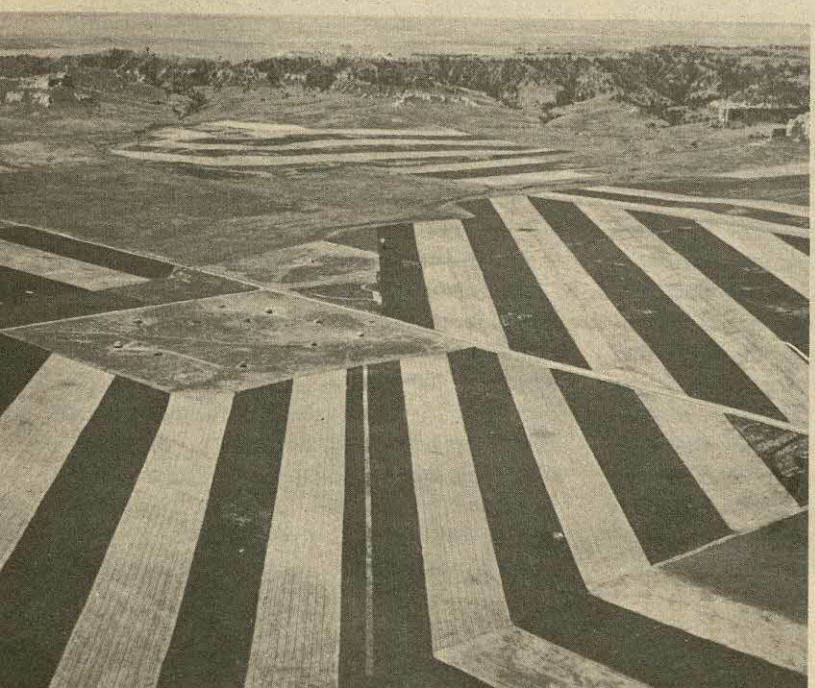
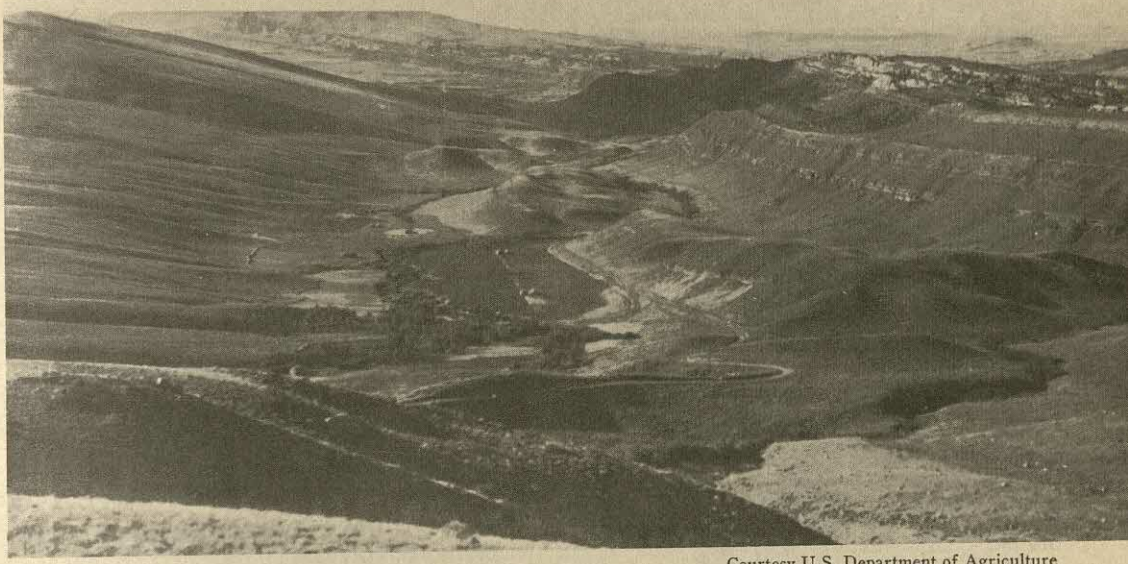


Fig. 160. Extensive wheat farming in the short-grass steppe region of western Nebraska (Banner County, south of Scottsbluff). Alternate strips of wheat and summer fallow. In this manner each strip of wheat can use the soil moisture of two seasons.

Courtesy Soil Conservation Service



Courtesy U.S. Department of Agriculture

Fig. 161. Short grass, semi-arid country in Wyoming. In the center an irrigated meadow for the production of supplementary cattle feed. Note how plainly rock structure shows.

to fenced ranches wherein pasturage of the native grasses is controlled more or less efficiently and is supplemented by fodder crops and, in some cases, by yard feeding. This change has nearly eliminated the cowboy as the picturesque character of earlier days. The "cow country" has been pushed into the drier regions of the Southwest, and but few of its original characteristics are now found within the Great Plains. In Argentina the cowboy,. called the *gaucho*, is still a picturesque figure, but even there he is gradually being shoved westward and southward by the encroachment of crop farming and fenced ranching. It seems certain that in Argentina, as in the United States, the activities of the cowboy will be confined to lands where rainfall will not support grain production, but where it is sufficient to maintain a grass cover (Fig. 161).

Sheep ranching predominates in the drier sections, where low rainfall, high evaporation, or poor moisture retentiveness of the soil result in sparse vegetation inadequate for cattle. It is an industry that may be considered transitional between the semiarid and the arid lands. Under poorer conditions some profits may still be made with goats. The livestock situation may thus be summarized by stating that the fat grazing lands are used for cattle, the sparse grazing lands for sheep, and the worst grazing lands, characterized by bush and hardy shrub, for goats.

Where water is available and markets accessible, extensive irrigation systems have been constructed, particularly in the United States, east of the Rockies, from Montana to New Mexico. The greatest degree of success has been achieved in the northern half of the Great Plains, because of the larger size of the rivers which head in the mountains and flow across that section. Similar projects have been developed on the Columbia Plateau. High yields per acre may readily be obtained under irrigation because generally the soils of semiarid regions are exceptionally fertile, and the alluvial lands are easily tilled. The crops which have proved most successful belong to one of two types, either those which need abundant moisture with much sunshine and give large cash returns per acre, or those for which local demands are comparatively strong. Sugar beets, melons, specialized fruits, and early-season vegetables are examples of the former, while feed and forage to supply the local grazing industry illustrate the latter.

Since the areas under irrigation are small in comparison with the unirrigated uplands, the needs of the ranches for feeds to supplement the ranges, especially in winter, result in comparatively high prices for the forage and grain crops produced in the irrigated valleys. Furthermore, the ranchers of the Great Plains find it advantageous to finish beef cattle for the market, so far as possible, prior to sale, and for such purposes quantities of alfalfa, sorghums, and grains are demanded.

The production of specialized crops such as sugar beets, plus the production of feed crops for local markets, has given great impetus to the development of irrigation projects in the semiarid regions of the United States. This development has not been equaled in any other semiarid area of the middle latitudes. The belief that the national welfare of the entire country would be enhanced by making the slightly productive areas more productive, and thus adding to the national income and to national strength, has been an important factor in promoting this development. On the other hand, irrigated land frequently is high-cost land, which must produce high-value crops. If the crops so produced are already in surplus, or can be produced profitably only when granted the protection of high tariffs or similar devices, this belief might well be challenged by the taxpayers and consumers who must pay for the projects and products.

THE OUTLOOK. No climatic regions demand more careful study of the question "To what purpose should the land be put?" than do those of the semiarid type. Sound policies of land utilization must be based upon a knowledge and consideration of many factors. The topographic features, quality of the soil, native vegetation, length of growing season, severity of winters, heat of summers, the amount, seasonal distribution, and annual variability of rainfall—all are factors of major importance.

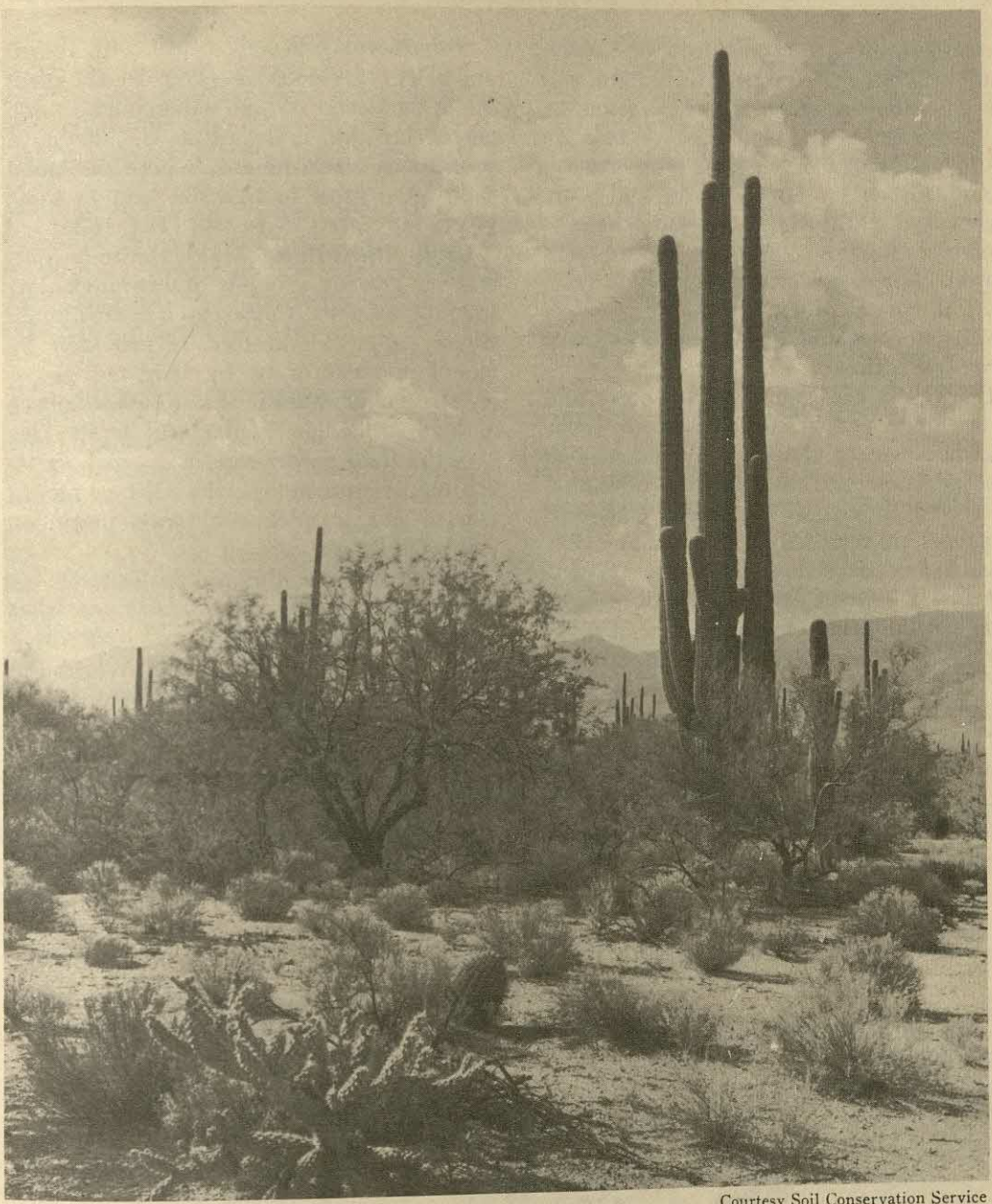
Economic returns from these regions depend upon the selection of such crops as are adapted to the existing natural conditions. For cultivated crops, methods of tillage to conserve moisture must be employed. The ability of the soil to withstand wind action and the erosive effect of dashing rains should be carefully studied before the native vegetation is disturbed. The economic factors should be given careful consideration. Crop production should be favored only where profitable returns may be reasonably certain on a basis of average or even below-average conditions, and should be discouraged in all sections where such returns can be expected only under the most favorable weather and market conditions. Large areas of semiarid lands still await more reasonable exploitation in Asia, South America, Canada, and in the United States.

It is to be hoped that the mistakes of the past, wherein, during wet years, lands were broken and put into tillage regardless of soil conditions, may not be repeated. When several wet years follow one another in succession, as they may be expected to do, let owners and users beware lest they extend the cultivated acreage into areas where only grass can be permanently successful. Grass is nature's adaptation of arid land to the climate. Man should study carefully all the factors and the probable results before he destroys the sod.

THE INTERMEDIATE ARID TYPE OF CLIMATE

The deserts of the middle latitudes, as a class, are not so completely desolate as are those of the low altitudes. In the latter, temperatures are high throughout the year, humidity is low, and the intensity of evaporation is great, whereas in the middle latitudes evaporation takes place slowly during the several months of the cold season. Furthermore, the average annual rainfall is slightly greater in most of the middle-latitude deserts than in those of the low latitudes. As a result of the somewhat larger amount of rainfall and its greater efficiency in providing soil moisture, the scattered xerophytic vegetation is more abundant in the cool than in the warm deserts.

The best-known middle-latitude deserts are in southwestern United States and central Asia (see World Map of Climatic Regions). The deserts of the Great Basin and the Mojave of California are examples of



Courtesy Soil Conservation Service

Fig. 162. Semi-desert vegetation in southern Arizona. The tall cacti are saguaro. A cholla cactus and a barrel cactus appear in the foreground. The low trees are palo verde. Note wide spacing of brush. Vegetation of this general character is a near approach to the desert.

the former, and Takla Makan and Gobi, with much sparser vegetation, of the latter. All are interior basins practically surrounded by mountains which prevent the inflow of vapor-laden winds.

Climatic conditions. The climatic conditions may be summarized in a few broad general statements. The average annual rainfall is less than 10 inches in most places, although in cooler areas desert conditions may not be reached until precipitation falls below 6 inches. Diurnal and seasonal ranges

of temperature are pronounced; the maximum in summer is comparatively high, and the minimum in winter is low. In summer, days may be hot and nights cool. Winds are strong and irregular. Freezing temperatures at night persist later in the spring and begin earlier in the fall than is generally the case in humid climates of the same latitude and altitude. Since, however, deficiency of rainfall is the one dominating cause of low productivity of the land, the other factors are of little significance.

Desert soils are generally gray, coarse, and stony. Sharp changes of temperature cause disintegration of the rock by mechanical processes, and this results in the formation of relatively coarse materials. Chemical processes are retarded by coolness and dryness, and decomposition therefore proceeds but slowly. Because of low rainfall there is little leaching, and since much of what soaks in returns to the air by surface evaporation, the dissolved mineral salts are not carried away but are left in the upper part of the soil. Desert soils are rich in soluble alkali minerals, sometimes so rich that plant growth is impossible, and they are low in humus because of the scantiness of the vegetative covering.

Vegetation. Woody brush with thorns and hairy or resinous leaves typifies the plant life of the desert. Where winters are severe, herbaceous and fleshy plants die down, in contrast to warm deserts, where perennial cacti often grow to tree size and in some places into forest denseness (Fig. 162).

Land utilization. Middle-latitude deserts are grazing grounds of extremely low carrying capacity. Cattle can be grazed only where supplemental feed is provided by mountain pastures or by irrigated crops. Sheep ranching is the most widespread phase of land utilization in the arid lands. But even this industry depends in no small measure upon pasture lands in the adjacent mountains or upon supplemental forage produced under irrigation.

In arid lands of the middle latitudes, as in those of the low latitudes where other forms of livestock fail, the goat may thrive (Fig. 163). While in the New World the pressure upon the land has not forced maximum utilization of desert wastes to the extent that it has in the Old World, and therefore the goat has not become so common, goat raising is an industry of considerable importance on the Edwards Plateau of Texas, an area of steppe climate. However,

Fig. 163. Scene in the arid lands of Mongolia near Ulan Bator (formerly Urga).

Courtesy American Museum of Natural History, New York. Photo by Roy Chapman Andrews.



in Arizona and New Mexico goats are kept successfully in areas of near-desert conditions. The goat is the last word in land utilization; where the land is too rugged or dry for goats, man can hardly expect to succeed with other forms of livestock. Only when pressure upon the land in the United States has become much greater than it is at present, may we expect economic conditions to make goat raising in the desert wastes of the Southwest increasingly profitable.

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15

Principal Agricultural Products of the Intermediate Regions

AGRICULTURE OUTSIDE the tropics, and particularly in the regions of intermediate climates, is essentially dissimilar from agriculture in the tropics. Its methods are different, it produces different crops, and it must meet different problems.

In the tropics subsistence agriculture prevails; commercial agriculture is frequently carried on in the form of large-scale capitalistic enterprises under technical management, although in recent decades small-scale native commercial agriculture has been increasing in importance.

In the intermediate regions commercial agriculture prevails and is carried on in the form of comparatively small-scale individual enterprises, although in some parts of the world large-scale capitalistic or communistic farms have developed. Nevertheless, there are still many areas where the farmers produce primarily for their own immediate needs, and even in regions where agriculture is highly commercialized part of the production is generally used by the farm family.

In the tropics the land can produce throughout the year, but in most regions outside the tropics a cold season limits production. Shorter growing seasons and lower average temperatures make it necessary to grow crops that are hardier than those raised in the tropics. Thus there is, on the whole, little overlapping in the types of crops produced by the two major agricultural zones of the world, the tropics and the middle latitudes. Where the former grows rice, cassava, millet, sorghum, and yams as major foodstuffs, the latter produces wheat, rye, and potatoes. Corn is the only major grain that plays an important role both in the regions of intermediate climates and in the subtropics and tropics.

The animal industries, of secondary importance in most regions of warm climates, play a vital role in the intermediate regions, producing enormous quantities of raw materials—notably leather and wool, for industry, and meat, fats, and milk for food. The tropics produce small quantities of animal fats but large amounts of vegetable fats, some of which are indispensable to modern industry.

Relatively few products of commercial

agriculture are common to both the tropics and the middle latitudes, the principal ones being sugar and tobacco. Although tropical sugar does compete with sugar produced from beets, and could do so even more successfully if no tariff restrictions existed, many of the tropical tobaccos, because of their unique aroma, really should not be considered competitive with those raised in the intermediate climates. Tropical fruits likewise are largely noncompetitive because they differ so materially from the so-called temperate fruits. Thus, the products of tropical and middle-latitude agriculture are so diverse that they give rise to an extensive commercial interchange, a trade necessary to the welfare of the people of both these climatic zones, and one which should continue to increase in volume so as to make it possible to raise the standard of living of all.

Among the numerous agricultural products of the middle latitudes, only those are discussed here which are of great importance from a world point of view and which enter international trade in relatively large quantities. In the regions of intermediate climates, production of fruits and vegetables on a commercial scale considerably exceeds similar production in the tropics and subtropics; but in comparison with the other products of agriculture, their importance is so small that they are not included in the following discussion.

WHEAT

The most important food of the inhabitants of the middle latitudes and dry subtropical regions long has been, and in many areas still is, some form of bread. Archaeologists, searching for remains of human occupation and human life in the ages that preceded the period for which we possess definite historical records, have often found caches of grain, and sometimes even evidence of breadmaking. In the Book of Genesis man is ordered to earn his own bread, and the principal prayer of Christianity includes a reference to this all-important staple food.

Wheat is the best breadmaking grain, and thus wherever man has settled in the intermediate and dry subtropical regions he has planted it. From ancient times it has been a staple crop on which not only the life of individuals but even the stability of states has depended.

Climatic adaptability of wheat. The wide geographic distribution of wheat, from central India to southern Finland and from Central America to the Peace river, was made possible by its adaptability to various climates. This adaptability is largely a result of the fact that botanically the genus wheat (*Triticum*) consists of several species, most of which have developed numerous varieties, adapted to various sets of environmental conditions. Among the principal species of wheat should be mentioned common wheat (*Triticum vulgare*), club wheat (*T. compactum*), spelt wheat (*T. spelta*), durum wheat (*T. durum*), rivet or cone wheat (*T. turgidum*), Polish wheat (*T. polonicum*), and emmer (*T. dicoccum*).

Notwithstanding its great adaptability, wheat cannot be grown in some extensive areas because of adverse climatic conditions. Where winters are long and severe and summers cool, with growing seasons of less than a hundred days, little wheat is produced. It is virtually absent in the regions with a subpolar type of climate; in both North America and Eurasia these regions approximate the broad belt of northern coniferous forests (see World Map of Climatic Regions).

Equatorward the limiting factor is essentially a combination of temperature and humidity. It is not altogether impossible to grow wheat under tropical conditions, but the plant becomes so susceptible to diseases that such a possibility is only of academic interest. Practically speaking, wheat is not produced in regions of humid tropical climates. The warm limits, however, vary considerably from place to place. In humid subtropical regions, as in southern China and southern United States, wheat is of little importance. In the dry subtropical regions however, wheat is the principal grain. There it is sown during the late fall and early winter, matures during the late spring, and is harvested in the early part of the dry summer. Under such favorable

climatic conditions wheat is grown in rather low latitudes in North Africa, Egypt, and Israel. On the dry western part of the Deccan Plateau of central India, where a tropical savanna climate prevails, the cultivation of wheat extends to within 15 degrees of the equator. This, however, is an exceptional case; nowhere else within the tropics is wheat grown extensively, except at high altitudes, where the climate is not tropical.

The planting season—winter and spring wheats. The common distinction between spring and winter wheat refers primarily to the time of planting and does not necessarily indicate a difference in species. By slow adaptation spring wheats may be changed into winter types, and vice versa. A wheat which is sown in the fall on the plains of northern India, where mild winters prevail, might have to be sown in the spring on the plains of Nebraska and Kansas, where the winters are rather severe. In some countries it is difficult to distinguish clearly between fall and spring varieties. In northern Africa the sowing season lasts well into January, while in southern Argentina it does not end until the first half of August, the equivalent of our northern February. If the winters are severe enough to kill a high percentage of the wheat plants, the sowing generally is done in the spring. This is the case where frosts come early, and average winter temperatures are low.

On the average, winter wheat tends to yield more heavily and is a more dependable crop than spring wheat. Therefore, wherever the climate allows it, the farmer will produce winter wheat in preference to spring wheat.

Moisture requirements. The optimum precipitation for wheat seems to lie somewhere around 32 inches per year, varying, of course, with seasonal distribution and with temperatures. Where temperatures are relatively cool, excess moisture has a decidedly unfavorable effect. Thus, little wheat is grown in the rainy coastal lands of Oregon, Washington, British Columbia, Ireland, and western England. On the other hand, wheat still does well where precipitation is considerably below the optimum, and under such conditions its yields are affected less than those of most other crops.

As a result of this ability to grow where most other grains do not give satisfactory yields because of lack of moisture, the cultivation of wheat has in many parts of the world been pushed into subhumid and even semiarid lands. An additional reason for this is that under conditions of low rainfall high-protein wheats are produced, and these, being eminently suitable for breadmaking, command a higher price than do the softer wheats of the more humid regions. In the latter regions, also, higher-yielding and more profitable crops such as corn tend to push out wheat economically. This is, for example, the case in Iowa, where physical conditions are favorable for wheat, but where during the last decade the average wheat acreage was only 170,000, while that of corn was about 10,500,000 acres.

The subhumid and semiarid lands of the middle latitudes generally had an original stand of grass. The scarcity of water and timber on these grasslands long formed obstacles to their agricultural utilization. The soils, black chernozems and related soils, are, however, very fertile because the low rainfall prevents the loss of valuable plant salts through leaching and because the age-long grass cover enriched the soils with humus materials that impart the dark color (Fig. 164).

Soil requirements. Wheat prefers fertile silt or clay loam soils, especially those which contain a certain amount of lime. On the stony, glacial soils of New England, where corn gives satisfactory yields, wheat has never done well, except during the first few years of cultivation. Although in this case climatic and soil factors are difficult to separate, the latter undoubtedly strongly affect yields. On the well-drained, fertile, marine clay silts of the Netherlands and northwestern Germany, wheat is successfully grown, but on adjoining sandy and infertile glacial soils it cannot be economically produced.

Colonization of the temperate grasslands. In Russia the settlement of the southern grasslands, or steppes, proceeded only slowly during the eighteenth and nineteenth centuries, partly due to insecure con-

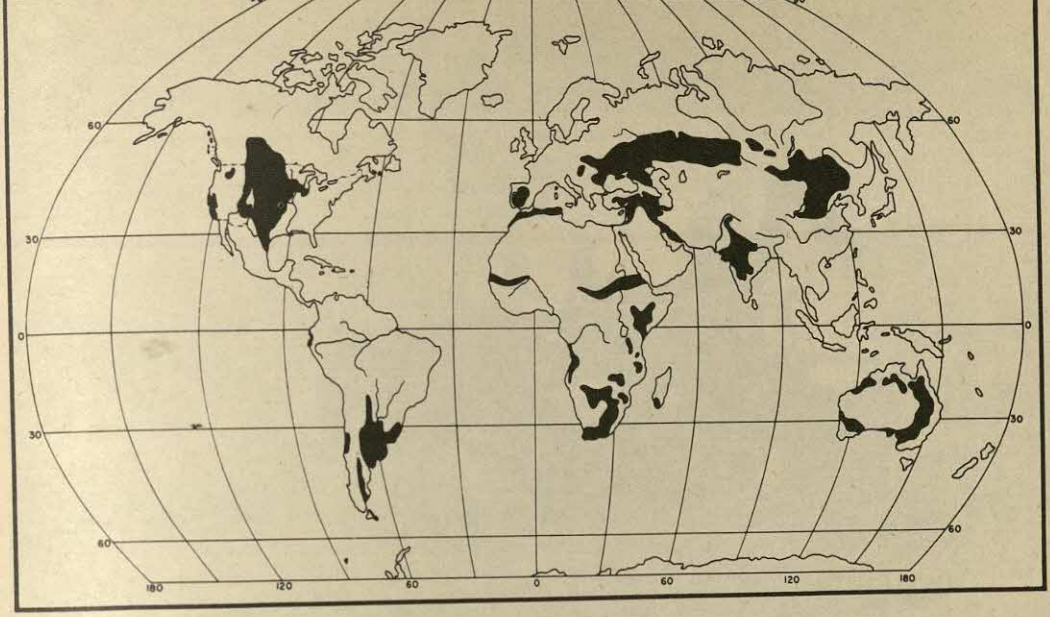
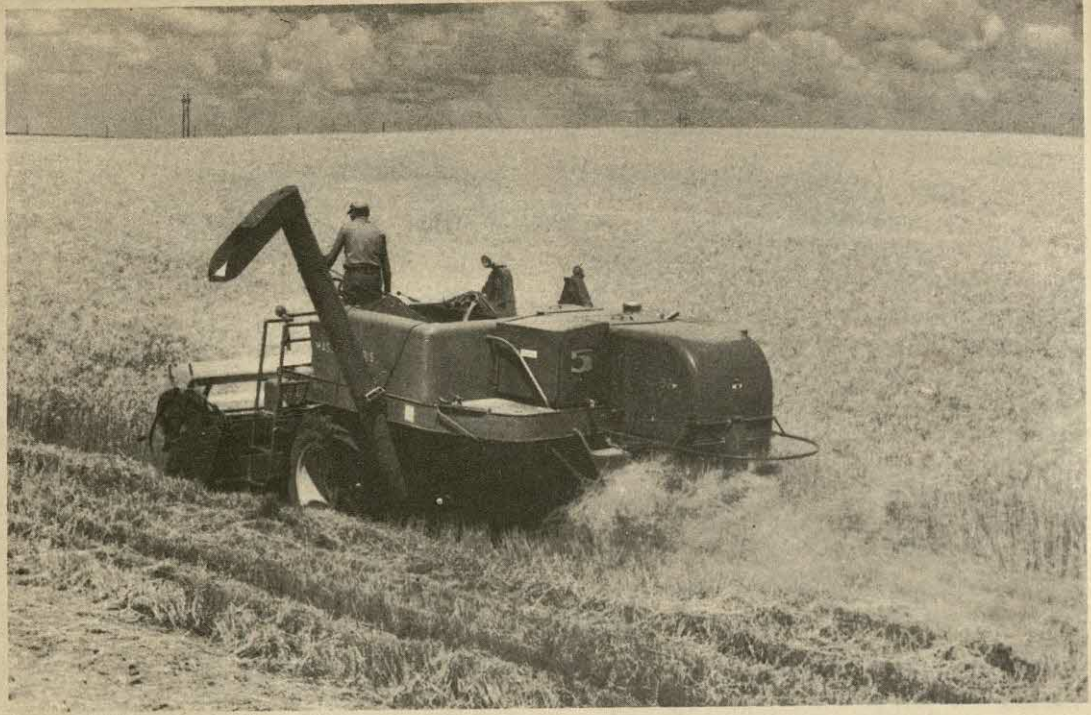


Fig. 164. Principal areas of black soils and related soils of the middle latitudes, and areas of somewhat similar soils in the tropics.

ditions but partly also as a result of the fact that the steppe environment was quite different from the forest environment to which farmers were accustomed. Likewise, in other parts of the world farmers accustomed to an agriculture developed in forest regions long regarded these grasslands as unfit for anything but the cattle industry. Extensive tillage agriculture did not become practical on the subhumid grasslands until the latter half of the nineteenth century. Then, with the aid of modern agricultural machinery and well-drilling equipment and with the facilities offered by railroad transportation, extensive farming became profitable on large areas formerly deemed unsuitable for tillage (Fig. 165). Wheat was the staple crop which gave the quickest returns on the initial expenses of colonization. Thus, within a brief period, the subhumid and semiarid lands outside the tropics became not only large producers of wheat but also its chief exporters. As a repercussion to this revolutionary development in world agriculture, the acreage of wheat declined in Western and southern Europe and in the United States east of Chicago. In Western Europe this development caused the severe agricultural depression of the 1880's and 1890's. In many countries government protection of the wheat industry has tended to retard this downward trend, or even to reverse it.

Principal wheat-producing regions. Even with the limitations imposed by landforms, climate, soil, and economic and social factors, wheat is grown widely in the intermediate and subtropical regions for both subsistence and commercial purposes. Among the important producing countries are several where most of the production is for the home market and where the crop therefore has only an indirect influence upon world trade and world prices. Among these should be mentioned Italy, India, and China. Because of their large populations, however, they not only consume practically all they produce, but generally import considerable quantities. The principal producers from a commercial point of view are the United States, Canada, the USSR, Argentina, Australia, and France. France has periods during which it is an importer and other periods during which it exports; during the 1950's production increased to the point where it now is a significant ex-



Courtesy U.S. Department of Agriculture

Fig. 165. "Custom" combining of wheat near Alliance, Nebraska. Trucks will come alongside to receive the grain. Note the size of the wheat field and also how much of the stalk remains.

porter, despite a large internal consumption. Argentina and Australia, both of which are large exporters, produce much smaller quantities of wheat than do France and Italy. However, their low internal consumption, due to small population, enables Argentina and Australia to export most of their crop.

Wheat in North America—limits of wheat cultivation. The world's most important area of commercial wheat production lies in the Great Plains of North America and extends from northern Texas to the Peace river district of Alberta (Fig. 166). It is limited on the north by the short and cool summers of the subpolar climate and on the south by the heat and humidity which increase toward the subtropical Gulf Coast region. Cotton and other crops replace wheat in the southern part of the United States because the climate there is less favorable for wheat, and this crop gives lower returns per acre. Approximately north of the Ohio and lower Missouri rivers corn far outyields wheat and thus replaces it, except for small amounts that are produced as part of the regular rotation of crops practiced in the area. Still farther north the higher returns from dairy farming cause wheat to be raised only incidentally and locally.

To the west, the percentage of the land in wheat gradually decreases with the increase in aridity. Along the entire western margin of the Wheat Belt lies a broad belt where wheat farming, and for that matter tillage agriculture in general, is decidedly hazardous due to the fluctuations in rainfall from year to year. Since in the western portions of this belt the precipitation of one year often falls below the minimum necessary to raise a crop, the accumulated precipitation of two or more years is used for one crop by means of "dry farming." The essence of this method of farming is to divide sections, usually one square mile large, into wide strips, which are alternately sown to wheat and left fallow with some tillage.

In this marginal zone the limit of wheat production swings westward and eastward.

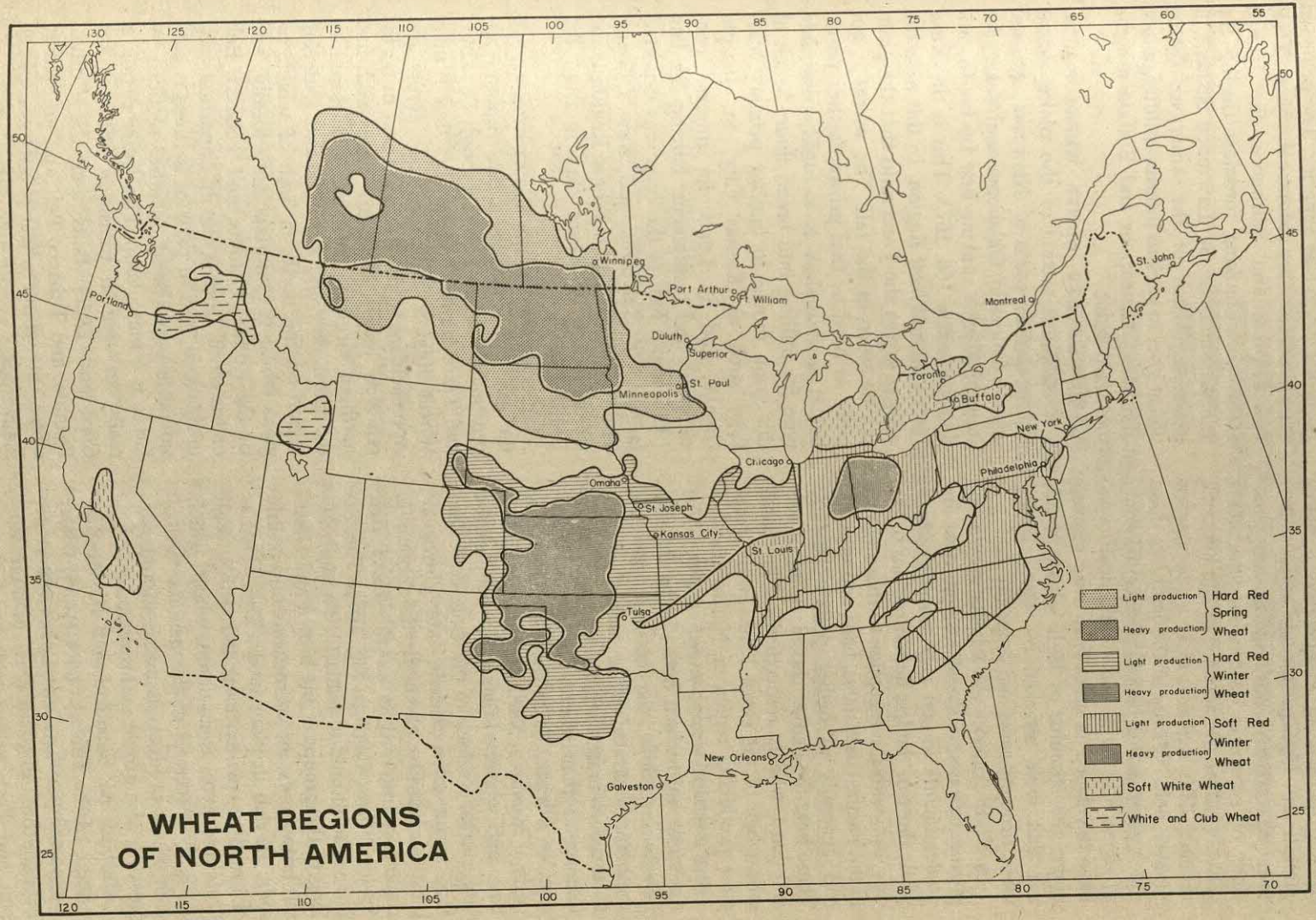


Fig. 166. Wheat regions of North America, according to type of wheat and intensity of production. Major milling and shipping centers.

During periods of comparatively heavy rainfall and high prices, agriculture tends to move westward. In dry years, and in periods of economic depression, agriculture retreats before the advance of the livestock rancher. This region is truly a "permanent pioneer belt." Misuse of the land has done much damage to soils in this marginal zone, as repeatedly large and small "dustbowls" have developed in areas that were plowed under the stimulus of high wheat prices, but that were attacked by wind erosion when drought came and crops failed.

In North America the wheats grown approximately east of the Mississippi river are predominantly of soft and starchy texture, while those of the less humid regions to the west are, with the exception of those grown in the Pacific coast states, hard and vitreous and generally of higher protein content. These bear the market classifications of soft and hard wheats respectively. The hard-wheat belt of the Great Plains is the foremost producing region of North America.

THE HARD RED SPRING WHEAT REGION. The American hard-wheat belt can be divided into two sections, the northern and the southern, separated by a narrow gap in ...thern Nebraska where corn is of more ...portance than wheat. The northern sec..., in Alberta, Saskatchewan, Manitoba, ...ts of Montana, North Dakota, South Da...ota, and western Minnesota, occupies the larger area. Because of the long, cold winters, spring-sown varieties are grown almost exclusively; therefore the region is commonly referred to as the *Hard Red Spring Wheat Region* (Fig. 166). The climate is subhumid to semiarid. The soils belong to the groups of the brown and chestnut-brown soils, the chernozems, and prairie soils, all rich in plant foods. The wheat is of excellent quality, hard and with a high protein content. Some durum wheat, which is highly esteemed in the manufacture of such wheat products as macaroni and spaghetti, is also grown in this region.

Most of the Canadian and a large percentage of the United States spring wheat is exported via the Great Lakes waterway, through the Canadian ports of Fort William and Port Arthur and the American ports of Duluth and Superior. The principal export centers are Montreal, New York, Philadelphia, and Baltimore, the United States ports ranking foremost during the winter when the St. Lawrence Seaway is icebound. Much of the American spring wheat goes to various interior milling points, of which Minneapolis and Buffalo are the most important.

THE HARD RED WINTER WHEAT REGION. The southern section of the plains wheat belt embraces parts of Nebraska, Kansas, eastern Colorado, Oklahoma, and Texas, the state of Kansas ranking first by far in production (Figs. 166, 167). This is the *Hard Red Winter Wheat Region.* In this area the winters are so short and mild that the grain can be sown in the fall. The wheat is not quite as hard as that grown farther north, but it nevertheless is a highly desirable type for milling into bread flour. Much of this grain moves to interior primary markets, such as Kansas City, St. Joseph, Omaha, and St. Louis, for internal consumption and reshipment. During the late 1950's about half of the crop was exported largely via Galveston and New Orleans. The Hard Red Winter Wheat Region is the major source of wheat exports from the United States.

THE SOFT RED WINTER WHEAT REGION. To the east and south of a line running approximately from Tulsa, through St. Louis and Terre Haute, lies the *Soft Red Winter Wheat Region,* which reaches across the Appalachians to the Atlantic coast in northern New Jersey, Delaware, Maryland, and northern Virginia. This area is bordered by the Corn Belt and the Hay and Dairying region on the north, in both of which regions wheat is important only locally, and by the Cotton, Peanuts, and Tobacco Belt on the south. Corn is also an important crop in this area, and in parts of it there is considerable pastureland. In other sections tobacco is a major crop. The entire region is really an area of transition between the Corn and Dairy Belts and the Cotton, Peanuts, and Tobacco Belt and an area in which soft winter wheat is only one of the main crops.

The wheat is winter sown and rather soft,

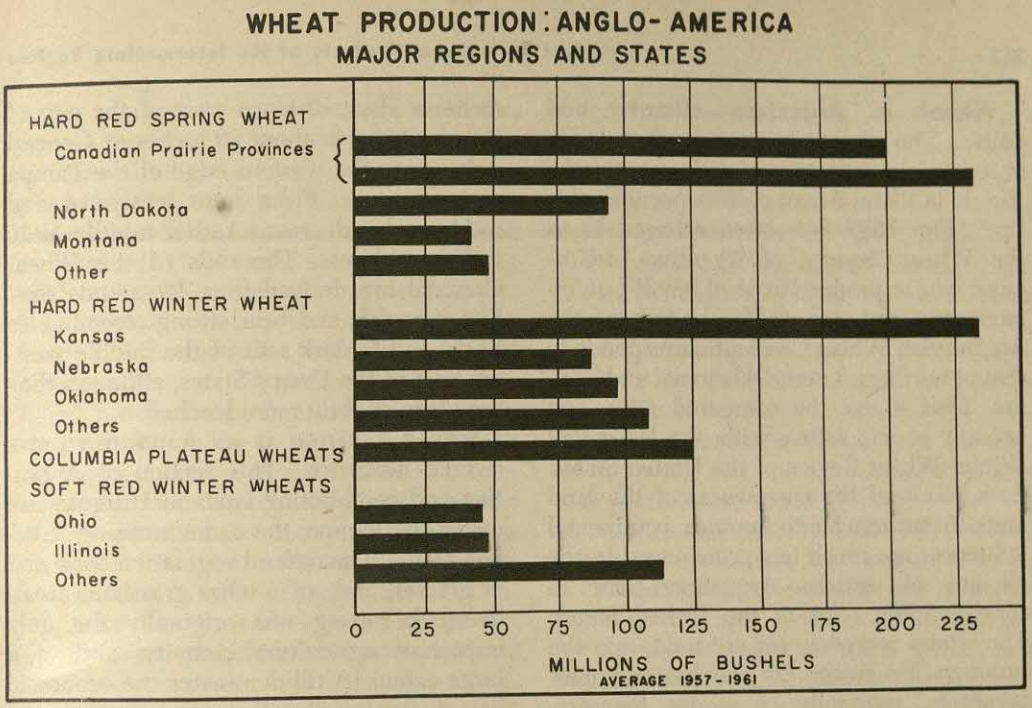


Figure 167.

owing to greater humidity. On the whole it is not as well suited for bread flour as the harder varieties grown farther west, but it makes high-quality pastry flour. The eastern Soft Red Winter Wheat Region accounts for about 13 per cent of the total wheat acreage in the United States. Most of the soft wheat is consumed within the country.

THE COLUMBIA PLATEAU REGION. Another important center of wheat production is located on the Columbia Plateau of Washington, Oregon, and western Idaho. Various types are grown in this region. The winter climate is mild, and although some hard red winter wheat is grown, especially in drier locations, softer varieties of white and club wheat dominate. Most of the crop is consumed in the western part of the United States, but large quantities are exported from Portland and neighboring Pacific ports to Europe and the Far East.

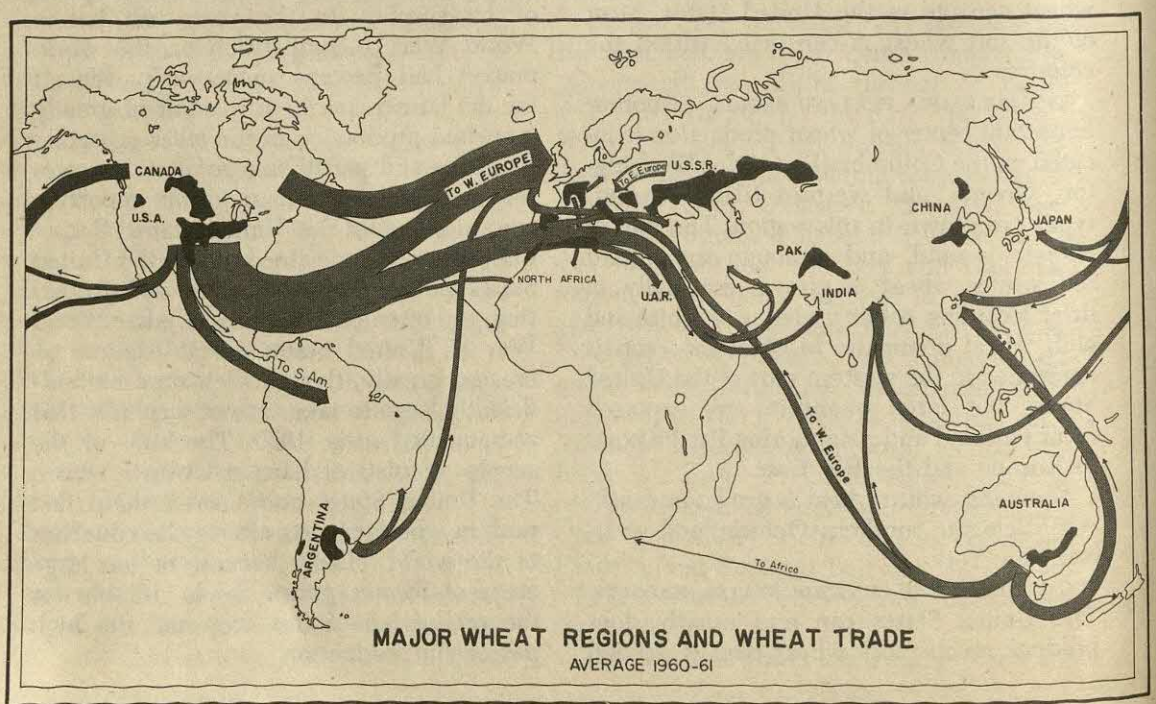
Some soft white wheat is grown in southern Michigan, southern Ontario, and western New York.

CANADIAN AND UNITED STATES EXPORTS. The United States can and usually does produce much more wheat than is needed to meet domestic demands. Wheat is a cash crop and is better adapted to the climatic conditions of a large part of the subhumid plains than is any other grain. Therefore, the wheat farmer has been greatly dependent upon foreign demands for the disposal of his surplus. In the years just before World War II competition on the world market had become increasingly difficult for the farmer, partly as a result of greatly increased production in the other exporting countries and partly as a result of the protectionist policies of many of the importing countries and of the United States. Consequently, exports declined so that the United States ranked below Canada and Argentina, and often below Australia. After World War II, United States wheat exports increased greatly, though they were not sufficiently large to take care of surpluses that accumulated after 1950. The bulk of the surplus consists of hard red winter wheat. The United States and Canada hold first rank in wheat exports among the countries of the world, chiefly because of the large areas of former prairie lands suitable for the production of this crop and the high per capita production.

Wheat in Argentina—climate and soils. The wheat region of South America is located in a huge semicircle around the Río de la Plata. Because of its peculiar outline (Fig. 168) it is often referred to as the "Wheat Crescent" of Argentina. In Uruguay wheat production is of small but inincreasing importance. The latitude of the Argentinian Wheat Crescent corresponds to that of northern Texas, Oklahoma, and Kansas. Thus it may be compared with, and actually is competitive with, the Hard Red Winter Wheat Region of the United States. As a result of the narrowness of the land mass of southern South America, continental influences are much less pronounced in the climate of eastern Argentina than in corresponding parts of the United States. The winter temperatures are mild, and the summers are warm. On the basis of temperatures, especially of winter temperatures, the climate of part of the area may be classified as humid subtropical. However, over much of the area, and particularly in the wheat crescent, precipitation is lower than in most other regions of comparable climate, ranging from about 32 inches a short distance west of the city of Buenos Aires to about 20 inches at General Acha, near the western edge of the Pampa region proper. From here westward and southward it decreases rather rapidly to 10 inches and less. The soils of the Wheat Crescent are derived from loess and loess-like materials and bear strong resemblance to the fertile dark soils of the middle western part of the United States, although they are often slightly more leached.

WHEAT FARMING AS AN ADJUNCT TO THE CATTLE INDUSTRY. This section of Argentina and neighboring lands in Uruguay are called the Pampa, the name meaning "treeless plain." The natural vegetation consisted of grasses, and, as in other grassland areas, livestock raising was originally the only important agricultural activity, and to a large extent it still dominates the economic life of the country. In many districts the cultivation of wheat is carried on in close association with the cattle industry. Areas of land are leased by the owners for short periods to immigrant share-tenants, the majority of whom are of southern European origin. At the end of the leasehold the ten-

Figure 168.



ant is required to leave the land in alfalfa, for which it has been prepared by the cultivation of wheat during several successive years. The tenant usually moves on to some other piece of land, where the same process is repeated. The harvest takes place during November, December, and early January; thus the wheat can be marketed when stocks in Europe, the principal center of consumption, are beginning to run low. Good rail facilities, improving road facilities, and the ability to export through such nearby seaports as Buenos Aires, Rosario, and Bahía Blanca aid in keeping down costs of transportation. Argentina, therefore, is an important factor in the world wheat market, ranking after the United States, Canada, the USSR, and France as an exporter. Areas of considerable extent are still available for wheat, and if market conditions should warrant it, production could easily be doubled.

Transportation facilities from farm to railroad have improved greatly in recent decades, resulting in an increased use of trucks. Although truck transportation is beginning to compete with rail transport for hauls longer than from farm to railroad, the bulk of the grain is still transported via the rail networks that center on the port cities.

WHEAT IN AUSTRALIA. In Australia wheat is the principal grain crop, occupying over two thirds of the area of tilled land. It is grown chiefly in the regions of Mediterranean climate, the leading states being New South Wales, Victoria, South Australia, and Western Australia. The winter rainfall ranges from 10 to 20 inches; at other seasons the rainfall is slight. In many districts dry-farming practices are necessary to assure a crop (Fig. 168).

Seeding generally occurs in the fall, that is, in April and May, and harvesting is done in late spring and early summer, the beginning of the dry period. Australia, like Argentina, thus enjoys the commercial advantage of being able to market its crop early in the year. The principal handicaps of wheat growing in Australia are: (1) great distances from the European market centers, and (2) unreliability of rainfall, which leads to great fluctuations in production. While Australia ranks below France and Italy in total production, because of its small population it ordinarily consumes only slightly over half of its crop, and so holds fourth or fifth place in export trade. The destinations of Australia's exports may change considerably from year to year. During the late 1950's most of the wheat exported was shipped north to the countries of Asia, and under half was shipped via the Suez Canal to Europe. In the past some wheat was sent in sailing vessels via Cape Horn, giving rise to the "grain race" to English ports. Since World War I the Far Eastern countries, especially Japan, have become important as markets for Australian wheat.

Wheat production in Europe and elsewhere. Europe produces a fifth of the world's wheat, more than any other continent. At the same time Europe is the world's greatest wheat import market, taking over half of the total traded. France is the only country of Europe which has periods during which it is a significant exporter.

The countries of Eastern Europe formerly were important exporters of wheat, the main centers being in the Lower Danube Basin of Romania and Bulgaria and in the Hungarian Basin. Russia, the greatest European producer, has exported appreciable quantities of wheat during many of the postwar years (Fig. 168).

In all three of these eastern areas the climate is decidedly continental, with cold winters and hot summers. The seasonal distribution of rainfall, with spring and early summer maximum, is favorable for wheat production. The amount of annual rainfall decreases eastward. In the Hungarian Basin it ranges from 28 to 20 inches, in the wheat districts of Romania from 24 to less than 16 inches; still farther east, in the wheat lands of the Soviet Union, it decreases eastward to an average of 12 inches in the lower Volga districts near Saratov and farther east into Asia. The natural vegetation over most of these areas was grass; the soils generally are fertile, either chernozems or chestnut brown and brown steppe soils.

In the Danube plains and in southernmost Russia, winter wheats predominate. In most of Russia, however, the snow cover

is too light to protect the plants from the effects of the severe winters, and therefore spring-sown varieties must be grown. In much of southern Russia the wheat industry is subject to the same handicaps as in the Great Plains of the United States. Winter snows and spring and early summer rains fluctuate greatly in amount from year to year, and deficiency of moisture often causes severe crop losses. It is in this part of the world that dry farming was first practiced.

The belts of black, chestnut, and brown soils on which most of the wheat of European Russia is grown extend across the Ural Mountains into Siberia. They gradually become narrower, and east of the Yenisei river they break up into isolated areas which continue to the brown and black soils of Mongolia and the Manchurian Plain. Wheat cultivation has followed this belt far eastward into Siberia (Fig. 168).

The quality of wheat improves from west to east with increasing aridity. The wheats of the Hungarian Basin and the lower Danube area are comparable with the hard red winter wheats of the United States, and some of the Russian wheats can be compared with the best hard spring wheats produced in Canada and northern United States.

In the black-soil or chernozem region and in the adjacent chestnut and brown soil regions which extend in a west-east belt from the Ukraine to Novosibirsk on the Ob river, the advance of Russian settlement has been accompanied by ever-increasing acreages of grain crops, principally of wheat. The expansion of wheat acreage began on a large scale during the previous century, but various Soviet five-year plans, especially the first (1928-32) and third (1938-42) and also the 1954-56 program, brought expansion on a scale larger than had ever occurred before. The ploughing of the steppe of "virgin lands," much of it short-grass steppe, between the Volga river and the mountain lands east of the upper Ob river has greatly increased wheat production. This area now supplies nearly half of the wheat of the Soviet Union, and the Ukraine is no longer the principal wheat-surplus region.

However, much of this land is marginal for grain, as is the western plains area of the United States. While good harvests of high-quality hard wheat can be obtained for a few years, fallow periods are necessary to prevent rapid decrease of soil fertility and particularly to prevent increased soil erosion. Whatever agricultural system is to be used in the driest portions of this area, it is imperative that it be a dry-farming system according to which only part of the available land is to be put to wheat each year. Despite the large increase in wheat acreage that has occurred in the "Virgin Lands," the droughts that occur from time to time and the short growing season (late May to early September) have restricted the increase in production. It appears that production demands for certain areas have sometimes exceeded local ability to produce, with the result that fallow periods became inadequate.

Among the other wheat-producing areas of the world should be mentioned northwestern India and Pakistan, northern China, and northern Africa (especially Algeria). The commercial importance of these areas is, however, relatively small.

Wheat yields. Yields of wheat differ greatly in accordance with cultural methods and climate. In the semiarid wheat-exporting areas of the United States, Canada, Argentina, and Australia, where farming is mechanized and extensive, yields of wheat average only 12 to 20 bushels per acre. In the Soviet Union 12 bushels per acre are obtained. At the opposite extreme is the intensive rotation agriculture of humid northwestern Europe, where wheat is raised on a small scale as an item in different well-established rotation systems, where livestock provides manure and where artificial fertilizers are used extensively. Here Belgium, the Netherlands, and Denmark have consistent yields of from 45 to 60 bushels per acre. In Italy yields are about 25 to 30 bushels per acre. In India and Pakistan yields as low as 12 bushels per acre are the rule.

Wheat as a commodity of international trade. Wheat not only keeps well during storage and transportation, but it is in great demand as a basic foodstuff in many parts of the world, especially in the middle latitudes. Although in some countries, as in the United States, per capita consumption has contracted slightly as a result of changes in the diet, in other countries, as in Japan, demand has been growing. Besides, good bread flour requires a considerable amount of careful blending of different types of wheat. For these reasons wheat has become one of the principal articles of world trade in raw products, and the trade in flour likewise is highly important, the United States being the leading exporter of flour.

The principal centers of consumption and deficit production are Western Europe and eastern United States. Both areas are densely populated and highly industrialized; furthermore, climatically they are better adapted to crops other than wheat. Of the two, Europe is the more important consumer. Large quantities of wheat are shipped there each year from Canada, the United States, Argentina, and Australia.

RYE

As a bread grain, rye is much less satisfactory than wheat. Whole rye bread, almost unknown in the United States, is dark brown, with a compact crust and usually somewhat soggy inside. It is frequently referred to as "black bread." In western and central Europe it was eaten chiefly by the lower income groups, but because of the social stigma attached to its consumption, a popular prejudice developed against it. Wherever the standard of living has risen and people can afford to do so, they tend to purchase wheat bread, or rye bread that has a considerable admixture of wheat flour.

The importance of rye as a bread grain is declining. It is still an important food in the Soviet Union and elsewhere in Eastern Europe. Immediately before World War II rye acreage and production in the Soviet Union amounted to about 65 per cent of that of wheat. In recent years both acreage and production have decreased to about one third that of wheat.

Although on the whole rye has decreased in importance as a breadstuff, it has increased in importance as a feed crop.

Rye as a crop of poor soils. Where soils are leached, acid, and too low in nutrients for wheat, and where the climate is too raw, rye is a grain that may still give a satisfactory yield. It needs less heat and can stand more moisture. Winter rye survives where most of the winter wheat would be frost-killed. Rye is autumn sown in most places, but both as a winter and a spring grain it reaches much farther north than wheat.

While it is grown to some extent on fairly good soils, rye is the typical grain of the poor, leached podzols which have developed upon the sandy glacial mantle rock and under the cool, moist climatic conditions in continental Europe north of the 50th parallel. Farther south rye occurs locally in areas of poor soil, unfavorable climate, or both, as on the Central Plateau of France, in Brittany, and on some of the sandier soils of the Hungarian Basin. Little rye is grown outside of Europe. In the United States the total rye acreage is small; the crop is grown on less favorable soils and in areas of comparatively cool climate in North Dakota, South Dakota, Nebraska, and Minnesota.

In comparison with wheat, the world trade in rye is of little importance. The principal exporting countries are Canada, Argentina, USSR, and the United States.

CORN

Although corn was not known to Old World agriculture until after the discovery of America, it is now one of the world's most widely produced cereals. It is used as a breadstuff by millions of people scattered over the warm lands of the earth. It is used as a feedstuff for domestic animals in many of the middle-latitude countries, and is a splendid raw material out of which swine and steers make choice pork chops and

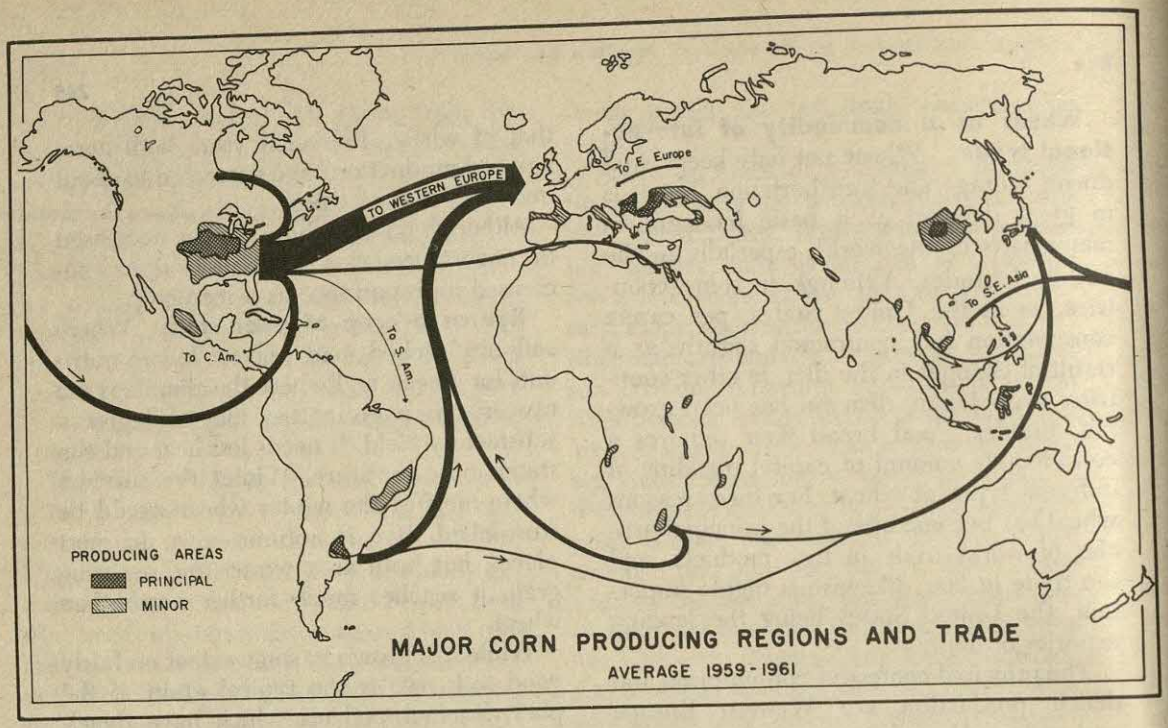


Figure 169.

tender steaks. In the United States numerous prepared foods are made from corn, such as grits, hominy, corn flakes, corn syrup, and corn oil. Industrial products by the dozen are or can be made from corn or corn stalks: for example, starch, alcohol, paper, rayon, and fiberboards. Corn cobs are still used as domestic fuel here and there (Fig. 169).

Corn is grown in every country in the New World from Canada to Argentina. It has become an important crop in Eurasia, from Portugal to China and Indonesia, and has been welcomed by the natives of Africa from the Nile delta to the Cape of Good Hope. Its numerous varieties are adapted to many climatic conditions: it can be produced where little rain falls, as in southwestern United States, or where rainfall is abundant, as in New England. It is produced where the growing season is only 90 to 100 days long, and where it is twice or thrice that length. It is tolerant of different topographic locations, its cultivation ranging from the low-lying coastal plains of eastern United States to steep mountain slopes of Colombia and Peru, where it thrives at altitudes exceeding 8,000 feet.

Thus corn is widely cultivated in regions with many different types of climate. It is found throughout the tropics, though it does not thrive well in drier areas or in areas of very humid climate. It is grown extensively in regions of humid subtropical climate, but conditions are less propitious in the regions of Mediterranean climate because of the dry summers. When irrigation water is available in abundance, it will even grow in desert climates, as it does in Egypt. In many of these areas, however, yields are not particularly high, and the crop is produced primarily for subsistence purposes. For example, throughout much of the region of humid subtropical climate in the United States, average yields run only from about 28 to 32 bushels per acre, against averages of well over 60 farther north, in Iowa. Examples of yields in some tropical countries are about 12 in Guatemala and Honduras, 14 in the Congo and Indonesia, 18 in Venezuela, and 20 in Brazil.

As a high-yielding commercial crop, corn has much more restricted limits. Long, warm summers with considerable rainfall, followed by autumns of little rain and quite cold winters are optimum climatic conditions. These occur not in the regions of tropical or subtropical climate, but in those

of humid intermediate climate. This is the major reason why corn is discussed in this chapter rather than in preceding chapters. Where favorable climatic conditions are combined with large areas of productive land, and where there are great markets for meat or for corn as a food, it attains major importance. The chief one of these areas lies in the United States (Fig. 169).

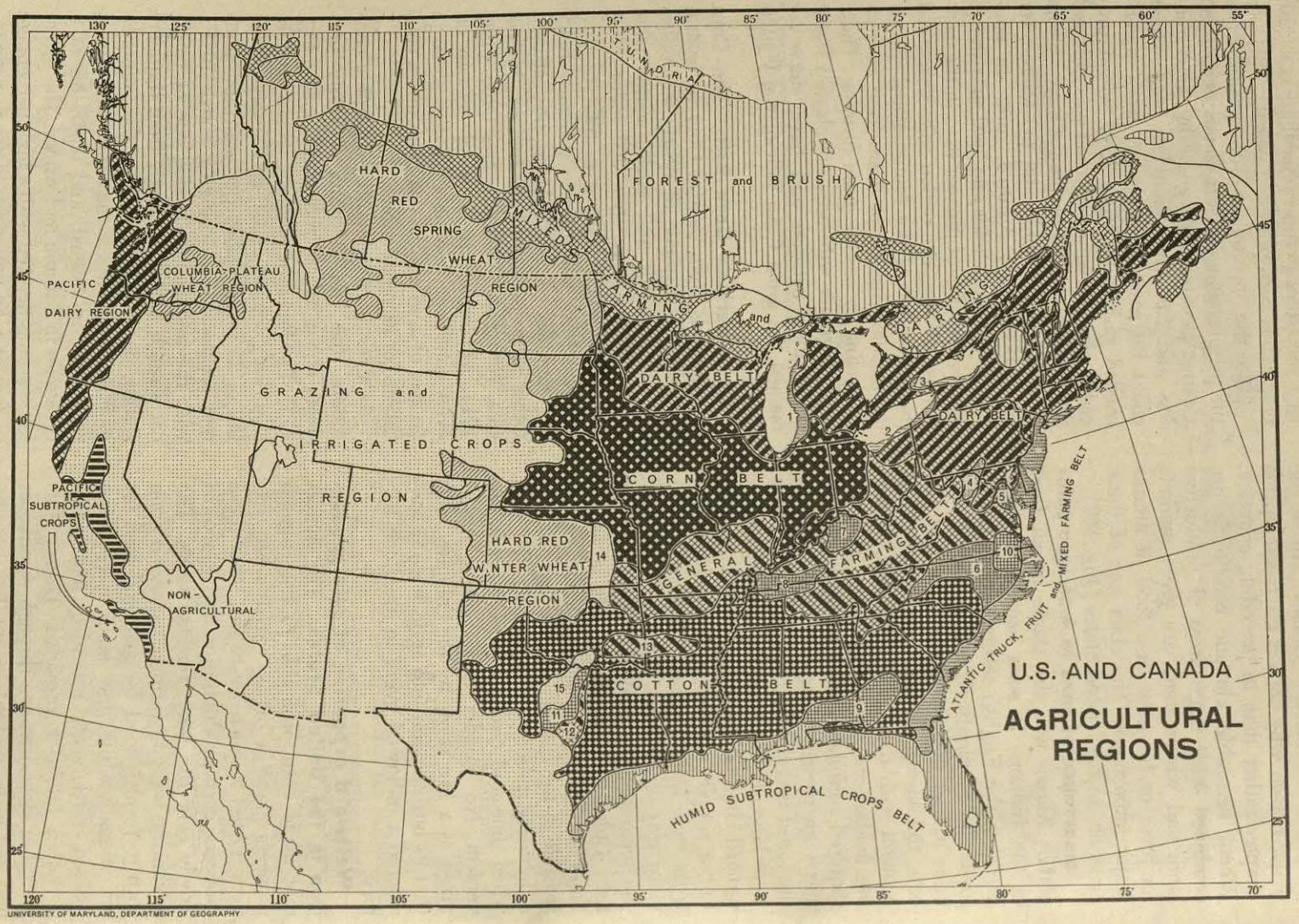
Importance of corn to American colonists. Maize was the staple cereal food of the Indians. It soon became a staple cereal in the English settlements of Jamestown and Plymouth. Under pioneer conditions it had distinct advantages over rye, oats, and wheat, the grains the pioneers had brought with them. For these small grains the fields needed to be plowed, and this required complete clearing of the land. At first such clearing was impossible because the forest was dense, and many of the trees were large. Corn, however, did not require plowed land. Girdling trees with an ax was but a simple process, and standing dead trees were little hindrance to corn culture. Corn was planted by hand in "hills," and the separate hills could be fertilized with fish. Cultivation required only a simple hand hoe, and as "storage on the ear" is feasible in the case of corn the harvest was a leisurely process of gathering the ears when time and circumstances proved convenient. No wonder corn became recognized as a life saver by the colonists, and that its introduction into agriculture is considered a hallowed event in American history.

Westward expansion of corn production in the United States. The factors that made corn profitable to the colonial pioneers made it highly useful when settlers started to push westward. With these pioneers, corn production moved westward slowly over the hilly, forested lands. The advancing wave of farmers depended upon corn to furnish food for man and feed for the animals while new lands were being cleared, settlements extended, and transportation facilities provided. During this period of slow advance through woodlands that had to be cleared before they became suitable for farming, corn was important as a subsistence crop rather than as a cash crop. Thus corn preceded wheat.

With the opening up of the prairie lands the picture changed: grasslands needed no clearing because they generally were treeless and free from boulders, and wheat could be sown immediately as a much-needed cash crop. Here, then, wheat preceded corn. However, the soil was rich and the summer rainfall ample for heavy yields of corn. Large fields and production for feeding purposes resulted, quite in contrast to the small fields and local subsistence corn production of pioneer days in the eastern woodlands. The period 1830-80 marked the conversion of the humid grasslands of the middle Mississippi Basin from an area of grazing to one of grain farming. These lands, together with adjacent cleared forest lands, then became and have since remained the great Corn Belt of the United States.

The American Corn Belt. The Corn Belt extends from central Ohio to central Nebraska, a distance of nearly 900 miles. Its width, north and south, varies from about 150 to more than 300 miles (Fig. 170). The states leading in total production are Iowa and Illinois, generally holding first and second places, respectively. Other major producers are Indiana, Minnesota, Nebraska, Missouri, and Ohio (Fig. 171). Although corn is widely grown on every continent, nowhere else does so large an area of land possess nearly optimum conditions for its production.

As a result of favorable geographic conditions, the United States regularly produces about half of the world's corn (Fig. 173). The favorable climatic factors include a growing season of 120 to 170 days, rainfall of 25 to 40 inches per year, and summer temperatures averaging above 70°F., with the midsummer period one of tropical warmth. Rainfall, mostly from thunderstorms, is heaviest during the summer months. It reaches a maximum in July, is still heavy in August, and tapers off to a minimum in autumn and winter. The growing season is favored with a high percentage of sunshine, an important factor in promoting growth of the plant. The dry, cold win-



UNIVERSITY OF MARYLAND, DEPARTMENT OF GEOGRAPHY

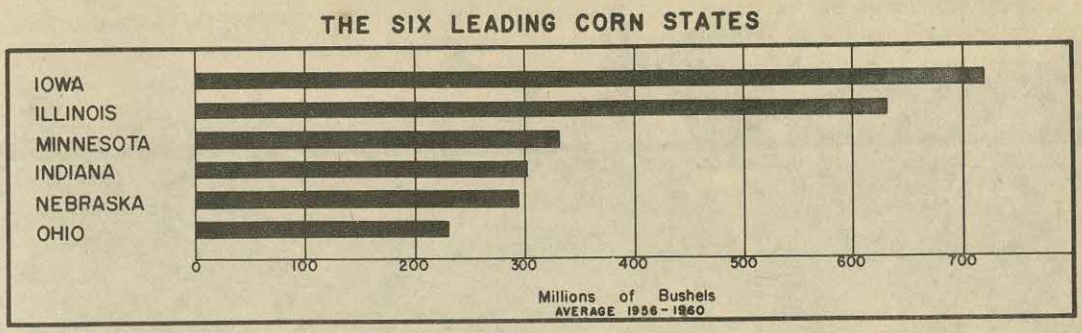


Figure 171.

ter facilitates storage at low cost with small percentage of loss by shrinkage or by insect pests; this is of great economic importance, whether the corn is marketed directly as grain or indirectly through the feed lot as pork or beef. Soils are fertile and easily tilled; in the eastern sections, where rainfall is heavier and soils therefore more leached, moderate quantities of mineral fertilizers have long been used, a practice that has gradually extended to the western section as well. The topography of the plains is conducive to the use of large-scale machine operations in preparing the soil, cultivating, and harvesting (Fig. 172).

Other geographic factors also contribute to the success of the Corn Belt farmers. The ingenious and inventive pioneers found this to be not only a land endowed with excellent soils and a stimulating climate, but also, especially in its eastern portions, a region with a wealth of mineral resources. Coal, petroleum, and natural gas are found in and about this agricultural region. These are basic materials of industry. The result is a rural landscape of large, productive farms, dotted with industrial cities, from metropolitan size, like Chicago and St. Louis, down to smaller centers, such as Muncie, Indiana, or Moline, Illinois. The cheap food supply, central location, and excellent transportation facilities are other factors favoring manufacturing.

Although the term *Corn Belt* is generally accepted as the designation for the area from Ohio to Nebraska and from southern Minnesota to northern Missouri, let it not be thought of as a one-crop country. Diversified rotation farming is the general practice. Only 50 to 65 per cent of all the land in grain is devoted to corn at a given time. Wheat and oats, nitrogen-bringing crops such as soybeans or clover, and other forage crops all hold prominent places in the agricultural scheme. Most corn farmers are also hog and cattle farmers. Surveys have shown that 80 to 85 per cent of the cropland is used to produce feed for farm animals. A large percentage of the corn is fed to livestock without leaving the farm of origin. Furthermore, large numbers of cattle from the drier plains west of the Corn Belt are shipped in for fattening before going to market as finished beef. These conditions

Fig. 170. Agricultural Regions of North America (opposite). 1, 2, 3: Lake Michigan, Lake Erie, and Lake Ontario fruit and truck regions; 4: Shenandoah-Cumberland valleys fruit and dairy region; 5: southern Maryland tobacco region; 6: North Carolina-Virginia flue-cured tobacco region; 7: Kentucky burley tobacco region; 8: Kentucky-Tennessee dark tobacco region; 9, 10, 11: Georgia-Alabama, Virginia-North Carolina, and Cross Timbers peanut regions; 12, 13: Grand Prairie and Southern Ozark-Ouachita general farming regions; 14, 15: Osage-Flint Hills and Arbuckle-North-Central Texas livestock regions. (Map after "Generalized Types of Farming in the United States," in Agricultural Information Bulletin No. 3, Bureau of Agricultural Economics, U.S. Dept. of Agriculture, 1950, by O. E. Baker, W. B. Hurd, and T. W. Grindley.)



Courtesy U.S. Department of Agriculture

Fig. 172. This machine, which is self-propelled, both picks and shells the corn, so that it can be "piped" directly onto a truck which is seen here approaching from the right. Scene in the Corn Belt in Ohio.

have made the Corn Belt the hog, cattle, and poultry belt as well. They have also led to the establishment of numerous meat-packing plants in and about the region, the greatest centers being Chicago, Omaha, Kansas City, St. Paul, and St. Louis.

However, within the Corn Belt are some areas where corn is produced for cash. The leading cash-grain areas are in the flat lands of east central Illinois and north central Iowa. Here, because of the lack of relief, soil erosion is at a minimum, the soils are deep, and a maximum of land per farm can be put in corn, whereas in most other parts of the Corn Belt more elaborate rotations are desirable.

Important types of corn. At the outset of this discussion the cosmopolitan character of corn was pointed out. There are hundreds of varieties of this New World cereal. Some mature in 90 days or less from time of planting, while others require more than twice that. Some are drought tolerant, others require great quantities of moisture. Some do well on lowlands, others are best adapted to higher altitudes. Many are varieties of *dent* corn (so named because the top of the kernel collapses slightly during the ripening process). These find their most favorable natural conditions in the American Corn Belt. The greatest improvement in corn has been the production of hybrids with higher and more dependable yields than ordinary open-pollinated corn. In 1937 about 8 per cent of United States corn acreage was planted in hybrid; by 1938, Iowa passed the 50 per cent mark; by 1940 the entire Corn Belt passed the 50 per cent mark; and at present nearly all plantings in the Corn Belt are hybrid corn.

Flint corn, a hard, smooth type of corn, is less used than dent, though it is common in the Southwest and Mexico. *Popcorn* is one variety of flint corn.

Corn in Argentina. Argentina produces only about one fourth as much corn as does the state of Iowa, yet it is an important exporter. The corn-growing area centers around the lower Paraná river region, but lies mostly west of the river in southern Santa Fé and northern Buenos Aires provinces; lack of adequate transportation facilities and social factors have retarded its expansion into adjacent suitable lands. Within a semicircle west of Rosario, with a radius of about 100 miles, there are broad expanses of well-drained rolling land eminently suited to corn production by power methods. There are no trees or boulders to clear away, and the soil is fertile and easily tilled (Fig. 169).

Climatically, Argentina is not quite as highly favored for corn production as is the Corn Belt of the United States. While the

annual rainfall averages only slightly lower, its distribution is less favorable, and the danger of drought is greater. Not infrequently considerable rain falls during the picking season, thus interfering with the harvest and causing deterioration in quality. The winters are less cold, and storage is more difficult. Transportation facilities and facilities for farm storage are inadequate in some of the corn-producing sections, and this multiplies losses through spoilage when rainy periods coincide with the harvesting and marketing seasons.

Insect pests constitute another handicap to corn production in Argentina. Northwest of the grain country is a stretch of semiarid shrub- and bushland which serves as a vast incubator for locusts and other insects. When their numbers become exceptionally large, and the food supply of their native habitat proves to be inadequate, they sweep southeastward and feast on the grainfields of the Pampa. On such occasions the corn crop suffers heavily. The net effect of the various adverse factors is a striking fluctuation in corn production from year to year.

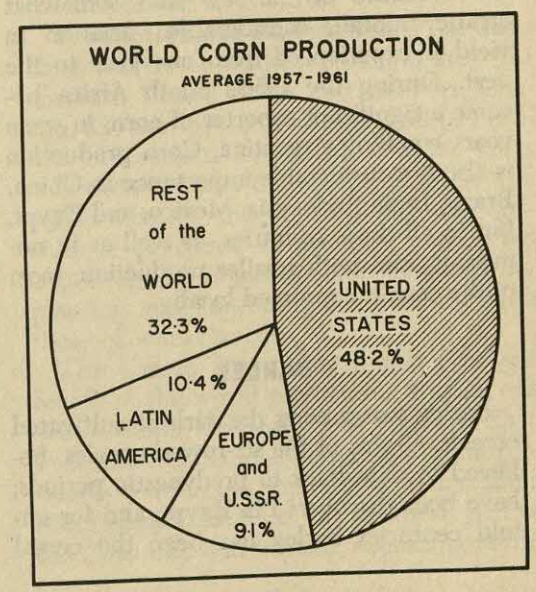
Argentina has, however, the advantage of producing its exportable surplus near the sea. Nearly all of the corn sold comes from within 200 miles of tidewater, and transportation costs therefore are low. The countries of northwest Europe are the chief buyers of Argentine corn. It is used there as feed for poultry and dairy cattle, for which use the Argentinian small-kerneled flint corn is preferred. The small, dense, dry kernels of this type of corn with concentrated food value are best suited to shipping, too.

A major reason for the importance of Argentina as a corn-exporting country has been the lack of development of a hog-raising industry in the country. Now that Argentinians have turned toward scientific improvement of their beef cattle and are finishing them into higher qualities for the market, hog production is increasing because hogs eat some feed wasted by cattle and thus can be profitably raised along with the cattle. With continued and increasing attention to higher-quality beef production and with expansion of the swine industry, the local markets may be expected to absorb more corn. In normal years almost two thirds of the corn grown in the Argentine corn belt is exported. Expansion northwestward of the corn area is unlikely, the lesser rainfall there being more favorable for wheat than for corn. However, there are possibilities of expansion farther eastward into the Argentine "Mesopotamia" between the Paraná and Uruguay rivers.

Corn in Europe. The corn belt of Europe lies just north of the summer-dry Mediterranean area and southeast of the cool, west coast marine area. The chief centers of production are the Hungarian Basin, which is shared by Hungary, Romania, and Yugoslavia with smaller portions in Austria and Czechoslovakia; the lower Danube or Walachian Plain of Romania, with adjacent areas in northern Bulgaria; the Moldavian Plain of eastern Romania and the adjacent Bessarabian Plain in southwestern USSR; and the Po Basin of northern Italy. Northern Spain and Portugal and southwestern France also produce corn.

On the fertile lowlands wheat and other cereals may be raised nearly to the extent of

Figure 173.



corn, but on rough steep lands, such as in the mountains of western Yugoslavia, corn tends to attain preponderance over other grains. Corn is used in many sections of southern Europe as food for man and as feed for livestock. As in parts of the United States, the dependence upon it as a food is a criterion of the wealth of the consumer. The poorer mountaineers there, as in the southern Appalachians, use corn as a chief foodstuff, and in many cases use it also in the form of a strong liquor.

Although the plains of southeastern Europe are considered to be the very heart of the corn region of Europe, the averages of production per acre are low. In Romania and Russia, the two countries leading in production, the average yields per acre are only about half of those in the United States. The use of rather dry lands or relatively poor slope lands for corn production and the occurrence of dry years are important factors in these results, but cultural methods may also be to blame. In the Hungarian Basin, yields both in Hungary and Yugoslavia generally are higher, but still do not come up to the American average.

Other corn regions. Corn production in South Africa has increased in recent decades. The main producing areas are in the Orange Free State and southern Transvaal on plateaus that have over 20 inches of rainfall. Because of the low and somewhat erratic rainfall, considerable variation in yield is experienced from one year to the next. During the 1950's South Africa became a significant exporter of corn, in some years equaling Argentina. Corn production is also of considerable importance in China, Brazil, India, Indonesia, Mexico, and Egypt, but in all these countries, as well as in numerous ones with smaller production, most of the corn is consumed locally.

BARLEY

Barley was among the earliest cultivated cereals. Grains of the six-rowed species, believed to date back to predynastic periods, have been discovered in Egypt, and for untold centuries barley has been the cereal depended upon by people who live near the desert's edge.

Uses and qualities. Barley ranks high in food value, but it has failed to gain high favor as a material for breadmaking because its gluten content is so low that it can be used only for so-called flat, unrisen breads. It is, however, widely used for soups, porridge, and specially prepared foods for babies and invalids. In cases of wheat shortage the use of barley offers a practical avenue of escape from a bread famine.

High-quality barley is used extensively for making malt. For this purpose the grain should be plump, thin-skinned, of pale color, and of high germinating quality. It should be rich in starch and relatively low in protein content. The color should be clear and uniform because discoloration precludes its use in the manufacture of beer, ale, or whisky.

Generally the principal use of barley is as a feed for domestic animals. Unlike oats, the straw has little value for feed and therefore is used chiefly for litter. The grain, however, makes good stock feed and may yield somewhat more heavily per acre than does wheat. It is in high favor as a forage crop for hogs, cattle, and horses, particularly where corn cannot be grown. In regions with winter rain and summer drought, as in California and Australia, it is often cut before the grain is mature in order to use the whole plant as hay. Cured at this stage it makes an excellent fodder crop.

Range and centers of production. Spring barley needs only a very short growing period, shorter than that required by spring-sown wheat, rye, or oats. As a result of this fact barley can be produced at the polar limits of agriculture, as well as at the limits of tillage agriculture in high mountain regions, and constitutes, for example, the principal grain crop on the high plateaus of Bolivia and Tibet.

The crop does not thrive in regions of high humidity and high temperatures. Hardly any barley, for example, is grown in the southern states of the United States, and in the humid tropics barley assumes importance only in a few highland areas,

such as in Ethiopia and on the high plateaus of Bolivia and Peru. It is, however, very resistant to dry heat, more so than wheat, and is produced comparatively close to the deserts in North Africa and the Near East. In North Africa it extends desertward to the very limits of tillage agriculture and is a common crop in the oases. In general, barley is a typical crop of regions with intermediate climate, but it becomes the principal grain only where climatic conditions are unfavorable for wheat or rye, as at the edge of the deserts, near the cold limits of agriculture, and at high altitudes.

Europe produces about a quarter of the world's barley. Heavy production occurs in a belt that reaches from the United Kingdom and France eastward into the Soviet Union. The USSR and the United States are the ranking world producers. Other centers of production outside Europe and the United States are Canada, Turkey, India and Japan.

International trade. International trade in barley is much more extensive than in either rye or oats. During the past decade 6 to 10 per cent of the world crop has entered export trade, the principal exporting countries being the United States, Canada, the USSR, Australia, and Argentina. The principal importing countries are located in northwest Europe, where there are large demands for barley to be used for malt and for feedstuffs for dairy cattle.

OATS

Oats constitutes one of the largest of the world's grain crops, the total production averaging more than 60 million metric tons yearly, compared with over 220 million for corn and over 240 million for wheat. Oats is used widely as food for humans and as feed for animals. The plant is hardy and tolerates comparatively low summer temperatures. Thus it can be grown quite far poleward, though it does not reach quite as far north as barley. Oats does not do well in warm moist and warm dry areas, and thus hardly any oats is grown in the tropics, and very little in the subtropics. It is a typical grain of the intermediate climates. The tolerance of oats for cool moist summers accounts for its prominence in northwest Europe, where it competes successfully with both wheat and rye.

In North America oats is widely distributed throughout the regions with humid intermediate climate, and the grain is well adapted to the range of soil and climate found within these areas. It is found also in the adjacent drier and more humid climatic regions. In the Corn Belt it is rotated with corn, wheat, tame hay, and a few other crops, and in the northern part of the belt it generally replaces wheat in the rotation; farther north, in the Hay and Dairy Belt, it is one of the main feed crops. Moisture-loving varieties from Scotland and other North Sea countries are produced in the humid northeastern states. Kherson oats, a drought-tolerant variety, is grown in the eastern Great Plains, from Texas to Alberta, Canada. In the southern part of this area, though varieties have been developed that mature before the onset of hot weather, hot dry weather frequently damages the crop. Very little oats is produced in the South. While oats is a spring crop, in the South much of the crop is fall sown, enabling the plants to head and fill prior to the advent of hot weather. The varieties used, however, are not very resistant to temperatures below the freezing point, a factor which limits expansion of oats in this area.

Production and distribution. The three chief centers of world production are: (1) northern United States and southern Canada, (2) northwestern Europe, and (3) central and eastern Russia. In all these areas oats thrives under the diverse climatic and soil conditions and fits well into the agricultural practices. It provides both grain and forage feed, and the labor demands for planting and harvesting conflict little with those of wheat or corn.

The United States contributes over one fourth of the world production; Russia, one fifth. Canada, Germany, both West and East, France, and Poland are other important producers. Within the United States, maximum production is found in the northern part of the Corn Belt and beyond, extending north-

westward into the Hard Red Spring Wheat Region of Minnesota and the Dakotas, although in the Corn Belt soybeans are tending to replace it. The states leading in production are Iowa, Minnesota, Illinois, and Wisconsin, the production of each generally ranging from 100 to 200 million bushels per year.

Although production is widely distributed in the humid and intermediate countries where horses provide the power, international trade in oats is small. Ordinarily only one to two per cent of the world's crop enters the channels of international trade. The value of the straw for feed and the bulkiness of the grain are factors which weigh against transportation and promote local production. Oats, therefore, has its chief markets near the districts where it is grown. Mills for preparation of breakfast cereals are important in this regard.

SOYBEANS

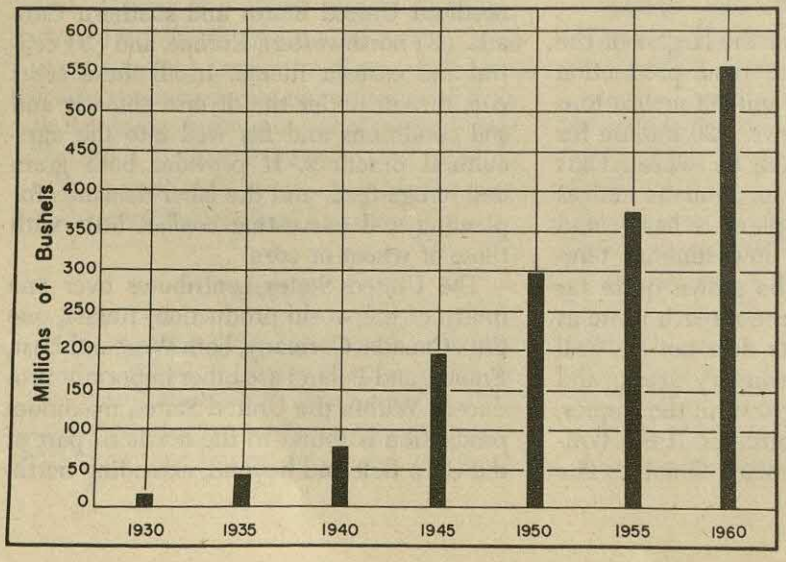
The soybean bids fair to become an important crop in most humid middle-latitude climates. At present it is produced on a large scale only on the fertile lowlands of China between the lower Yangtze river and the Hwang Ho in the Manchurian Plain, and in the Corn Belt of the United States. Botanically it is characterized by a large number of varieties, each of which is adapted to certain conditions of climate and soil. The length of the growing season required by these numerous varieties may range from less than three to more than six months. This flexibility makes the production of soybeans possible from Java to northern Manchuria.

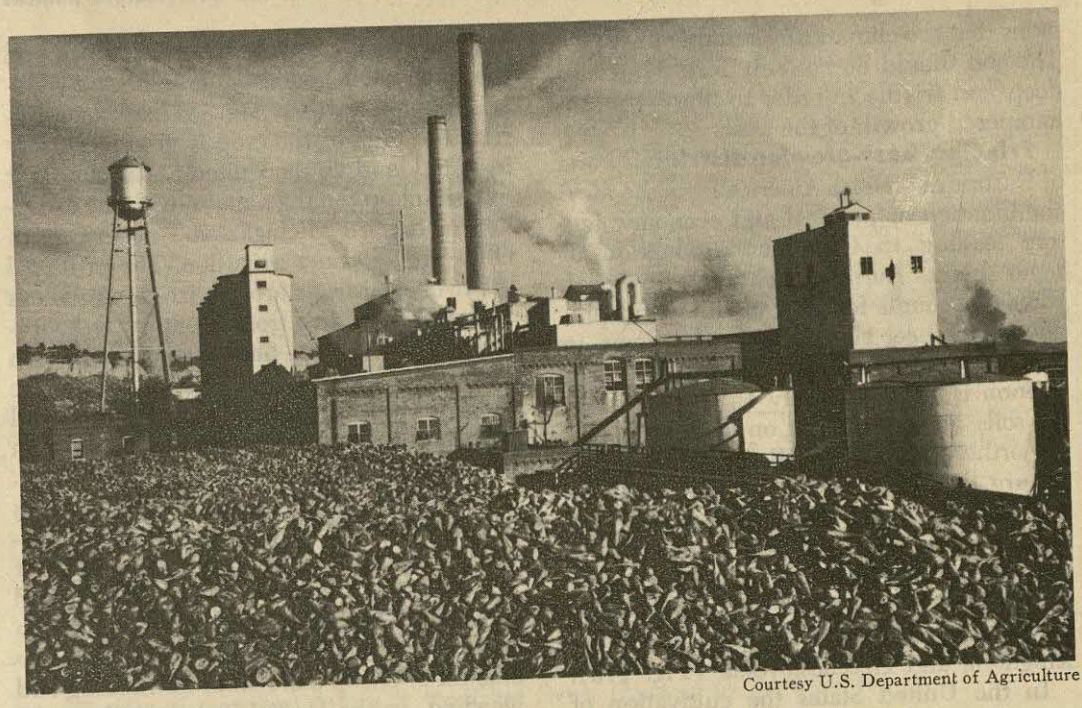
The bean is valuable as a food and a feed because of its high content of proteins and fats. In China and Japan soybeans are used for human consumption in many forms: sprouts, fresh or dried beans, meal for making noodles and other dishes, a cheeselike substance (the so-called bean curd), various sauces, and as a source for the extraction of oil and the manufacture of bean cake.

Commercial importance. Commercially soybeans are most important for oil and for bean cake. The Manchurian Plain, at one time the principal exporter, still is an important producing region. The oil is suitable for many industrial purposes, especially for the manufacture of oleomargarine, vegetable cooking compounds, paint, and soap. The residue, soybean meal, is pressed into cakes, and because of its high protein content it is valued as a feed and a nitrogenous fertilizer. In the United Kingdom, the Netherlands, and Denmark soybean cake is used extensively as a supplementary feed for dairy cattle, while Japan normally imports

SOYBEAN PRODUCTION IN THE UNITED STATES

Figure 174.





Courtesy U.S. Department of Agriculture

Fig. 175. Sugar beet factory in the High Plains area of the United States. Note the enormous quantity of beets that await processing, but must be processed quickly.

large quantities of it to serve as fertilizer.

As a result of the striking rise of soybean production in the United States Corn Belt, particularly since World War II, this country now produces more than China (Fig. 174). Soybeans and cottonseed are the leading sources of vegetable oil for margarine and cooking in the United States and far exceed in importance imported palm and coconut oils. The residual meal is a major cattle feed. The beans are raised in largest amounts in Illinois, Indiana, Iowa, Missouri, Minnesota, and Ohio.

SUGAR BEETS

Over one third of the world's production of sugar is derived from sugar beets, a crop which can be grown successfully only in intermediate climatic regions, where the summers are neither too hot nor too humid, and where the growing season is at least 130 days long.

Extraction of sugar from the beets requires the use of large and expensive factories. Thus, the sugar beet is a strictly commercial crop which must be sold to a nearby plant. On the other hand, much sugar cane is raised both for home consumption and for commercial purposes (Fig. 175).

Climatic requirements. The sugar beet has rather exacting requirements of climate and especially of soil. Summer temperatures should be moderate. In the United States it has been found that in the regions most favorable for the cultivation of sugar beets the average temperatures of the summer months (June, July, and August) do not depart much from 70°F. The supply of moisture must be ample, but too much summer rain will result in abundant leaf growth and low sugar content. Immediately preceding and during the harvest the weather should be dry and temperatures should be moderate, so as to insure the highest possible yield of sugar.

Soil requirements are particularly important for sugar beets, and this is one of the reasons why the crop is usually limited to fairly sharply defined areas within the re-

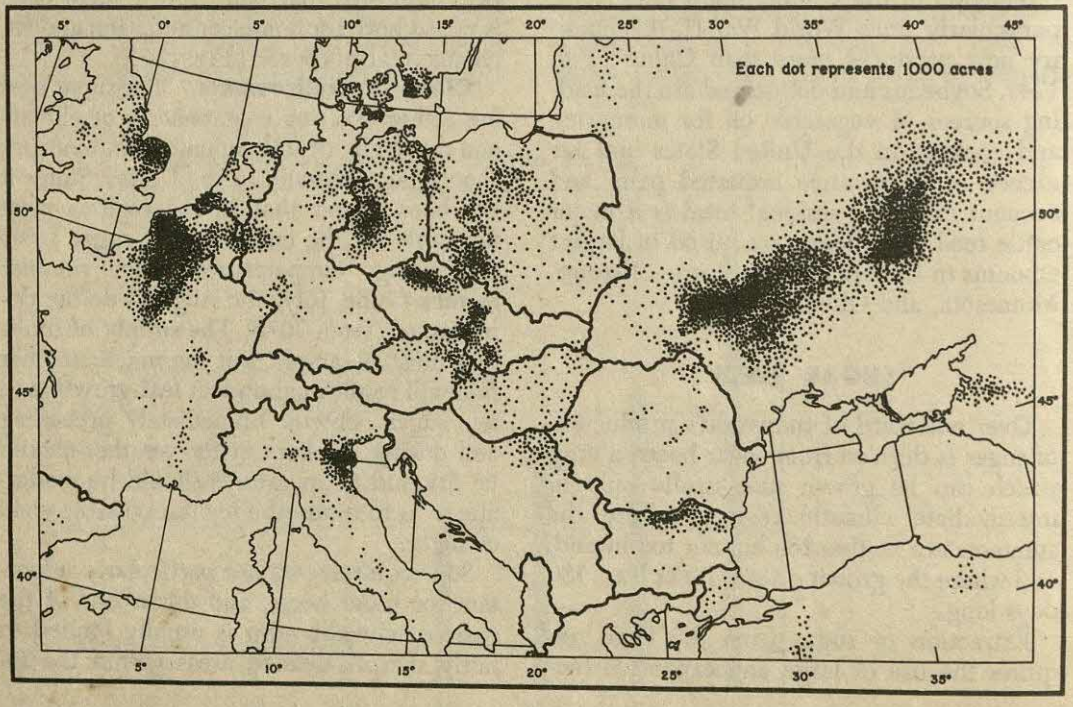
gions that are climatically suitable for beets. The soil should be not only fertile but also deep and friable in order to allow the unhampered growth of the beet.

Principal beet-growing districts. Parts of Europe and North America have the ideal combination of physical and economic factors leading to important production of sugar beets. Europe, including European Russia, accounts for most of the world production of beet sugar. Beets are grown in nearly all European countries, but their cultivation is successful only on the most fertile soils, as, for example, on the loessal soils of northern France and Belgium, the Magdeburg district in East Germany, Bohemia and Moravia in Czechoslovakia, and on the rich, black soils of the Ukraine. The countries leading in production of beet sugar in Europe are the USSR, Germany, especially East Germany, France, Poland, the United Kingdom, and Czechoslovakia (Fig. 176).

In the United States the cultivation of sugar beets is limited to the best glacial silt and clay loams east of the Mississippi and the unleached pedocalic soils of the semiarid regions farther west. Whereas in Europe the bulk of the crop is grown on nonirrigated land, in the United States the most important producing regions, with the exception of eastern Michigan and northwestern Ohio, are all under irrigation. The principal sugar-beet districts are the irrigated valleys of the Great Plains from Montana to southern Colorado, the Snake river valley in Idaho, the irrigated valleys of Utah, the Valley of California and the southern coastal plain of California. Colorado and California usually are the largest producers (Fig. 177).

Intensive culture. The sugar beet is particularly well adapted to a system of intensive agriculture as practiced in most of Europe since it requires deep plowing and careful tillage, the application of much manure and fertilizer, and the use of a large amount of cheap hand labor in thinning and weeding. In the United States much of the labor is performed by Mexican immigrants.

Fig. 176. Principal areas of sugar beet production in Europe. Note concentrations on the better soils of northern France, central Germany, the Bohemian basin, Silesia, the Ukraine, and the eastern Po basin.



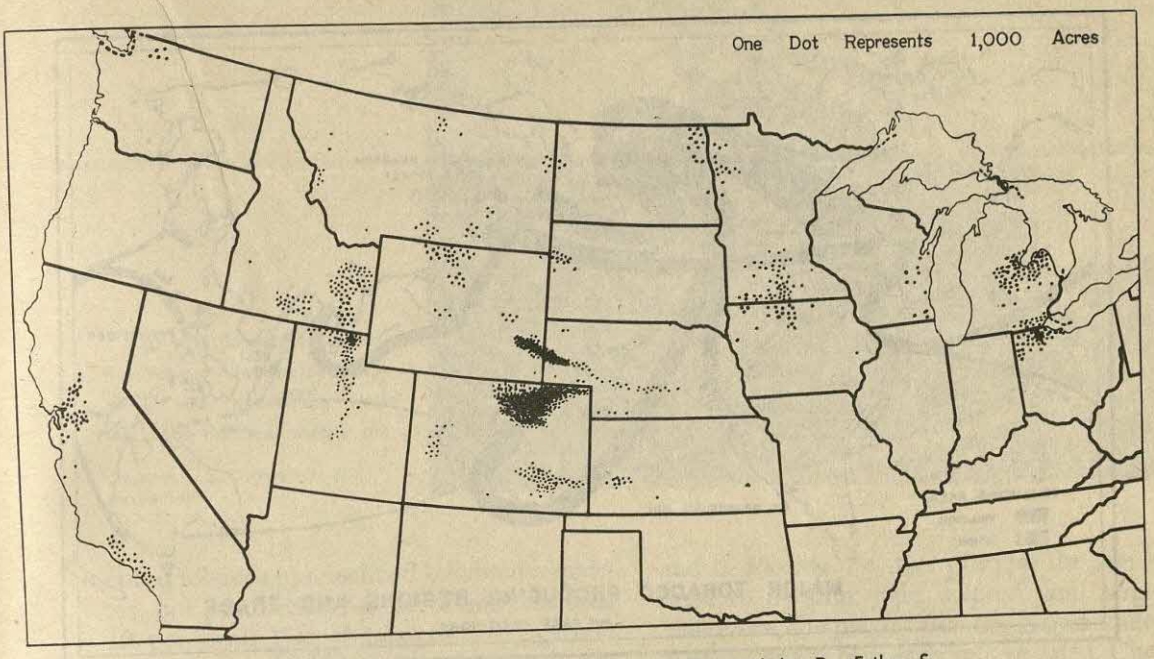


Fig. 177. Map of sugar beet districts in the United States. (Prepared by Dr. Esther S. Anderson, University of Nebraska.)

The by-products of the industry, beet tops and pulp, can be used to advantage in fattening cattle.

Beet sugar versus cane sugar. Since the yield of beet sugar per acre is generally lower than that of cane sugar, and the cost of production is much higher, almost all beet-producing countries protect their industry by means of tariffs against the competition of tropical sugar. Less beet sugar than cane sugar enters international trade.

TOBACCO

Tobacco is a truly cosmopolitan crop, in regard to its consumption as well as its production. In some form or other it is used by practically all peoples of the world, and its adaptability to climatic conditions is such that it can be grown from the equatorial belt to the northern part of the middle latitudes: from Brazil and Indonesia to southern Sweden and Canada. Obviously, tobacco is less dependent than are many other crops upon special conditions of temperature or length of growing season. The tobacco plant is a native of the highlands of Central America and northern South America and prefers considerable warmth and moisture; it does not thrive in a semiarid environment unless irrigated. Many of the important producing districts have developed in the warmer portions of the middle latitudes, and thus it appears justifiable to treat the tobacco industry in this chapter (Fig. 178).

The influence of soils. The geographic distribution of tobacco is influenced more by soil than by climate. The tobacco plant, esteemed for the flavor and aroma of its leaf, is like the wine grape, highly sensitive to slight differences in soil. The exact properties of soil that affect the quality of the leaf are not well-known, but experience has taught that some areas are better suited to tobacco than are others. As a result of this circumstance and of the economic inertia caused by established taste and purchasing habits, tobacco shows a very spotted distribution notwithstanding its wide climatic range. Certain types of tobacco are rigidly

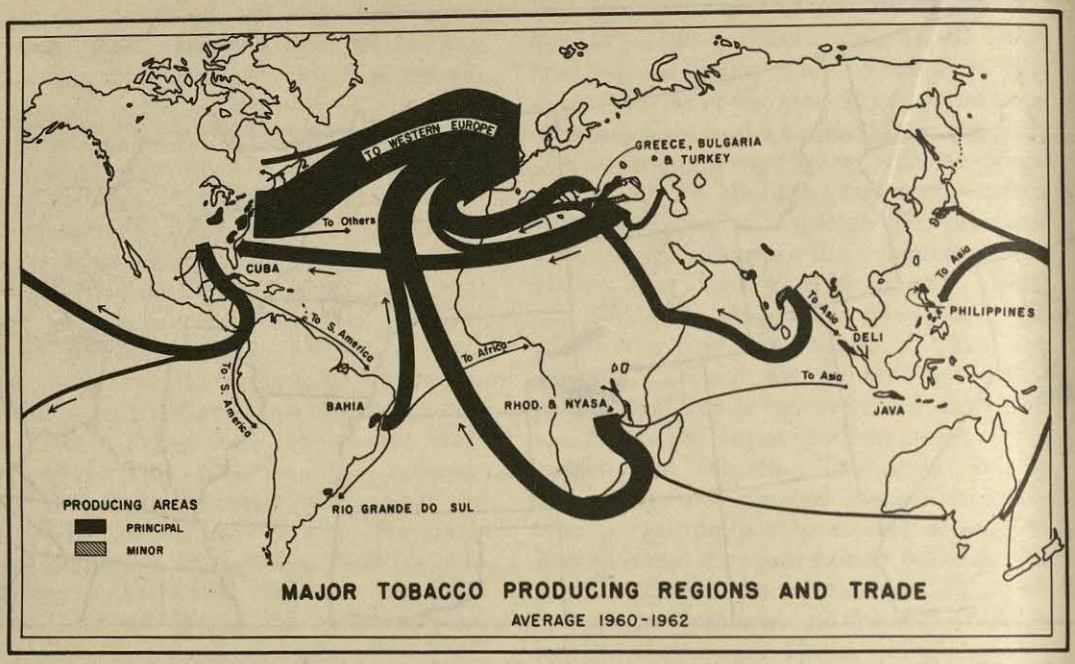


Figure 178.

bound to certain areas, and much of the tobacco of the world is sold on place-name specifications, for example, Maryland pipe tobacco, Virginia cigarette tobacco, and Deli cigar wrapper. It is interesting to note that an important center of Indian tobacco raising was located in Kentucky and Tennessee, an area which is now a principal producing district.

Curing of tobacco. The quality of the final product and, therefore, the uses to which the tobacco can be put are affected not only by soil, climate, and variety, but also by the mode of curing the leaf. In the United States the trade recognizes three well-known classes based upon the methods used in curing the leaf: air-cured, fire-cured, and flue-cured. Air-cured tobaccos are treated in well-ventilated barns without the use of artificial heat. Fire curing takes place in barns about three to five days after the leaves have been hung. Open fires are made on the floor of the barn and kept burning for several days. The smoke of these fires affects the tobacco and gives to it a characteristic odor and taste. In flue curing, the heat and smoke are circulated through the curing house in large pipes or flues and do not come into direct contact with the leaves. A light-colored tobacco results from this process (Fig. 179).

Tobacco in the United States. Flue-cured tobaccos are grown on the light, loamy soils of the Piedmont of North Carolina and southern Virginia and on the sandy soils of the Atlantic Coastal Plain of eastern North Carolina, South Carolina, Georgia, and northern Florida (Fig. 180). Most of the flue-cured tobaccos are used in the manufacture of cigarettes. The development of the tobacco industry in these regions illustrates how agriculture and the entire economy of a region may be profoundly affected by changes in habits of consumption. The increase in the demand for cigarette tobacco during the first half of this century led to a great expansion of the acreage of flue-cured tobaccos, from Virginia through North Carolina and South Carolina to Georgia and northern Florida. It also led to the development of a cigarette industry centered around Durham and Winston-Salem, North Carolina.

Since the mid-1950's the acreage of flue-



Fig. 179. Barns for flue-curing tobacco in Southern Virginia, with connecting work shed. The fuel now used is oil.

Courtesy U.S. Department of Agriculture

cured tobacco has declined by about a quarter, but production has decreased less than 10 per cent. Use of tobacco for cigarette manufacture increased by almost 10 per cent, but this increase was not sufficient to offset smaller exports.

Fire-cured tobacco is produced in the Piedmont of central Virginia and in the extreme western parts of Kentucky and adjacent Tennessee in the so-called "Black Patch." Its use is relatively limited, and the acreage is decreasing.

Among the air-cured types the Burley tobaccos of Kentucky and nearby areas stand first. These tobaccos are in demand primarily for pipe tobacco, but also for cigarettes. The darker and thicker leaves are used for the former, the lighter and thinner types for the latter. Throughout the Burley-producing areas acreage has decreased since the mid-1950's, though the decline has been smallest in Tennessee.

Tobaccos used in cigar manufacture are also included in the air-cured group. In the United States the quantities involved are much smaller than are those of the cigarette and pipe tobaccos. The areas of production are of limited extent and lie scattered through the states farther to the north—Wisconsin, Pennsylvania, and Connecticut being the leading producers. The most interesting feature of this aspect of the tobacco industry is the growing of cigar wrappers in the valley of the Connecticut river and in Florida. For this purpose the leaves need to be thin, light colored, and large. Therefore, the plants often are grown under artificial shade of cheesecloth or laths. Connecticut Valley shade-grown cigar-wrapper tobacco sells for about five times as much per pound as do air-cured and flue-cured tobaccos.

Tobacco in Europe and the Near East. In Europe much tobacco is grown locally, partly because in many countries the manufacture and sale of tobacco products has been made a state monopoly for revenue purposes. From a commercial point of view the principal producing regions lie in Greece, Bulgaria, Yugoslavia, and Turkey. There are grown the famous Oriental or "Turkish" tobaccos, especially prized for the manufacture of cigarettes. Among the best known are the tobaccos of Kaválla and Xanthe, grown on the north shores of the Aegean Sea (Fig. 178).

Other tobacco-producing centers. China, India, and East Pakistan are by far the largest producers in Asia, ranking in acreage and production next to the United States. Most of the tobacco, however, is consumed locally. India exports appreciable quantities of medium- and low-quality tobacco.

Indonesia used to rank next to the United States as an exporter, but since the war its production and exports have declined greatly. In Sumatra some of the choicest

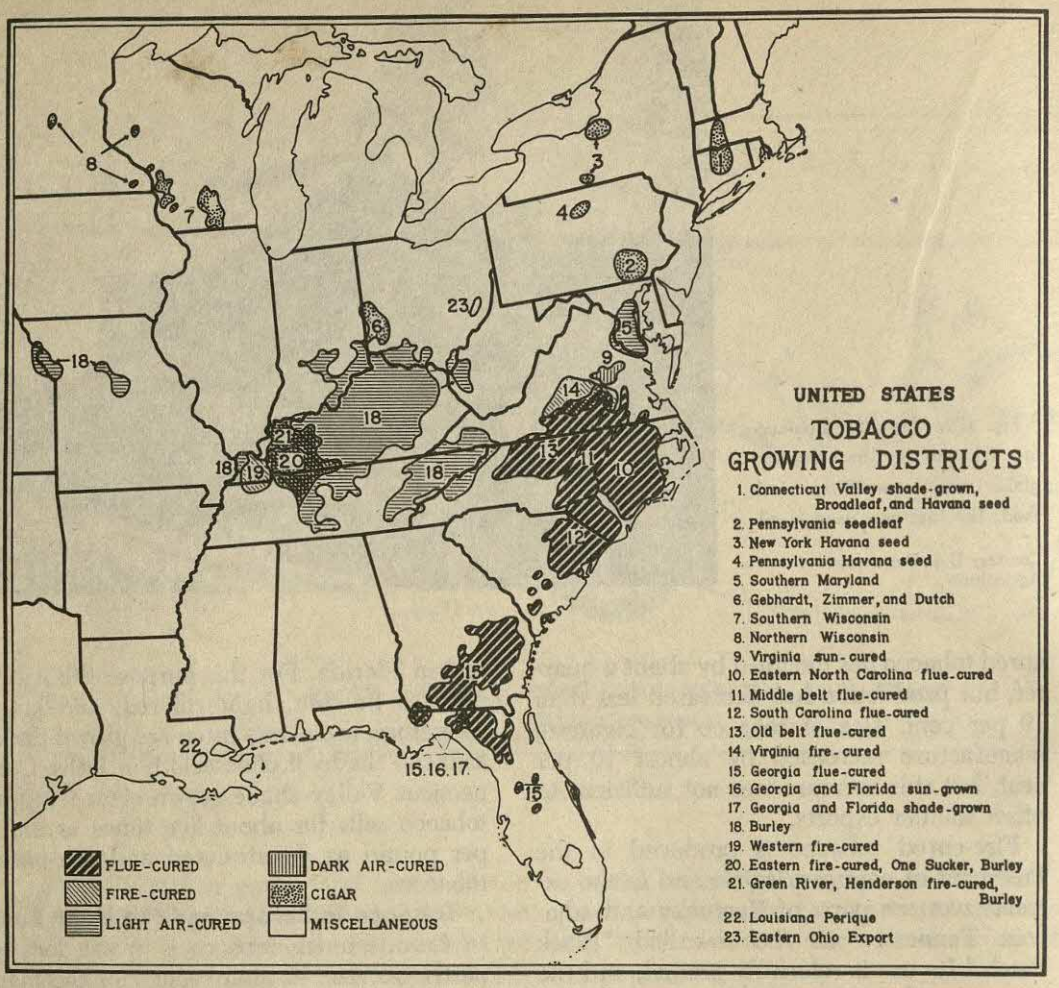


Figure 180.

wrapper tobaccos of the world can be grown on the fertile volcanic soils of the Deli region (on the east coast), where Western initiative and Eastern labor transformed a tropical jungle into a flourishing agricultural district. The eastern half of Java also produces much cigar tobacco.

The Philippines have long been famous for their excellent cigar tobaccos. "Manila" cigars are known the world over. The best tobacco, nearly all of cigar-leaf grade, is grown in the wide valley of the Cagayan river in northern Luzon.

Most valuable cigar tobaccos are produced in Cuba, Havana cigars being generally accepted as the world's best. The highest-grade tobacco is grown in the Vuelta district of westernmost Cuba and in adjoining areas. Most of the crop is raised under protecting cheesecloth by small farmers.

Other important centers of tobacco cultivation are found in the states of Baía and Rio Grande do Sul of Brazil; the former is well known as a center for producing tobaccos for cigar manufacture, the latter primarily for cigarettes. Southern Rhodesia and Nyasaland in southern Africa have become important producers of cigarette tobaccos since World War II. The crop is grown on European farms using native labor. South Africa has tobacco production for home consumption.

Tobacco in international trade. The United States is the world's principal exporter of tobacco and tobacco products, in normal years sending more than one fourth of its production abroad, mostly to Europe (Fig. 178). At the same time the United States imports (although in much smaller quantities, usually less than five per cent of

the domestic production) such types of tobacco as it cannot grow within its own borders.

The "Turkish" tobaccos of the eastern Mediterranean are exported mostly to Western Europe and for blending purposes to the United States.

The tobacco industry furnishes an excellent example of the great desirability and often the necessity of unhampered world trade. The difference in quality of tobaccos grown in various parts of the world naturally invite exchange, especially since extensive blending is practiced in both the cigarette and cigar industries. The United States, as the principal exporter, has probably the greatest stake in the maintenance and further development of the international trade in tobacco.

LIVESTOCK

In nearly all lands domestic animals play an essential role in agriculture. This is true not only of agriculture as practiced in the more progressive countries, but also of the simple types of farming which still prevail in many parts of the world. The peasants of southeastern Asia depend upon the water buffalo for the preparation of their rice fields, and the Negro farmers of the Sudan use the ox or the donkey wherever possible. Often the raising of domestic animals, even among primitive peoples, becomes an aim in itself. The Negroes of the East African plateaus consider a large herd of cattle a tremendous social asset, while in parts of the far north, for example in Lapland, the entire economic life of the people may revolve around the reindeer herd. Domestic animals are often indispensable for purposes of transportation. In the tropics, where good roads and railroads are few, domestic animals, though little used for other purposes, are essential as draft animals or as beasts of burden. In the great tropical desert areas the camel is still a carrier of freight and passengers, although in many sections of these regions the truck has become the chief means of surface transportation.

The animal industries are best developed in the regions of intermediate climates. These regions produce the principal surpluses of animal products, and horses, cattle, hogs, sheep, and poultry are of great importance in the agricultural scheme. In the polar regions the reindeer is the only domesticated source of food, and in the tropical latitudes the animal industries are handicapped by the coarse grasses, deficient in nutritive value, and the numerous animal pests and diseases that abound in a warm, humid environment.

HORSES

Domestic animals are kept for three major purposes: to provide men with food, material for clothing, and a source of power. The horse is without a peer for the latter purpose, and therefore throughout the centuries has been the principal beast of draft and burden available to man. Although originally animals of the semiarid grasslands, horses are now—because of their close association with tillage agriculture—most numerous in the humid intermediate types of climate, especially in Europe.

Distribution. The horse is not well adapted to warm humid climates. Where environmental conditions are unfavorable for horses, their role is often taken over by other animals, for example, cattle in tropical India, camels in desert regions, llamas or yaks in the high mountains, and reindeer and dogs in polar areas. Even in the subtropics horses do not flourish. In the southeastern United States and in the countries around the Mediterranean, mules and donkeys have always been more numerous than horses.

Because of their efficiency as draft animals, horses have been essential to successful agriculture in the middle latitudes, and therefore, notwithstanding rapid mechanization of farming, most of the horses of the world are still found in the humid intermediate regions. Horses have but slight importance as a source of meat or milk, except among a few nomadic peoples such as the Kirghiz, where the milk plays a role in the diet. They enter but slightly into national or international trade, and they are therefore of less economic importance than cat-

tle, swine, sheep, or poultry, whose products furnish a great variety of commercial commodities.

CATTLE

Two principal species comprise the bulk of the world's cattle: the taurine cattle (*Bos taurus*) and the zebu or humpbacked cattle (*Bos indicus*). The latter do well in the climates that are warm all year long. Not only are they tolerant of high temperatures and great humidity, but they are also able to thrive on coarse forage; they can, therefore, be raised in areas of seasonal droughts. In most regions no selection is practiced in breeding, and thus, as a whole, zebu are of limited value as beef cattle or milk producers. However, they make strong draft animals. Their resistance to disease in their areas of occurrence is much greater than is that of taurine cattle, a characteristic particularly important in tropical regions where parasitic insects and microorganisms flourish. In southern United States, especially in parts of Texas, zebus have been crossed with taurine cattle. The resulting breed has proved to be a fairly good beef animal which successfully resists the diseases carried by ticks and which can subsist on coarse forage.

In the low rice-growing districts of southern Asia the water buffalo (*Buffalo asiaticus*) is the principal domestic animal. It is thoroughly at home in a swampy environment, requires a daily bath, and likes to spend hours in the water with only its head and horns protruding. The water buffalo is neither a good beef animal nor a good milk producer, but its great strength makes it valuable for the laborious process of preparing the wet rice fields.

The taurine group, which includes a great variety of breeds, is best adapted to areas where mild to cold winters alternate with cool to warm summers, in other words, the middle latitudes.

Cattle raising. In many parts of the middle latitudes, and particularly in Europe, the raising of beef cattle, and often even small-scale dairying, is generally not a separate enterprise, but is integrated with a system of diversified tillage agriculture. The cattle consume those products which must be raised in the system of rotation but which are unfit for direct human consumption, such as legumes, grasses, and root crops. Their milk and meat are valuable farm products, while the fertility of the cropland is maintained partly with the aid of the animal manure. However, there are a number of regions in Europe where all other farm activities are subordinate to the production of milk.

Elsewhere, as in the Río de la Plata region or in parts of the American Corn Belt, the raising and fattening of beef cattle may be the principal aim of the farmer. In this case, tillage agriculture is carried on mainly for the purpose of producing feedstuffs such as corn and alfalfa, and the cattle convert these into commodities of higher value, such as steaks and roasts.

In still other regions, especially in the semiarid and arid lands, tillage agriculture is of little importance, and the natural vegetation, which consists mostly of short or bunch grasses, provides the basis for an extensive type of cattle industry. In such areas summer droughts often compel either the use of supplementary feed grown on irrigated land or migratory movements of the herds from winter quarters in low, snow-free plains to moist mountain pastures in summer.

The principal centers of cattle production are in the middle latitudes of Europe and North America. Important producing districts are also found in Argentina, Uruguay, Brazil, South Africa, and New Zealand. The world's greatest cattle population (including buffaloes) is in India, but it has very limited economic importance. India is followed successively by the United States, Brazil, and the Soviet Union.

In some of these regions cattle are raised primarily for beef, while in others milk and milk products are of chief importance. Both the beef and the dairy industries figure prominently in national as well as international trade.

Among taurine cattle certain breeds are most valuable as meat producers, whereas others rank as better dairy animals. Important beef breeds include the Shorthorns,

Aberdeen Angus, and Herefords, while the dairy industry is based largely upon the Friesian-Holsteins, Jerseys, Guernseys, and Ayrshires.

The beef industry in the United States. The raising of beef cattle is very important in the part of the Corn Belt west of Chicago. Large numbers of beef cattle are raised also on the farms and ranches in the Great Plains from Montana to Texas as well as in the valleys and on the mountain slopes to the west. In the Corn Belt not only are large numbers raised locally, but additional cattle are shipped in from the regions farther west. These "feeders" are finished for the markets on corn (Fig. 181). All through the Corn Belt, feed lots are characteristic features of the farms, particularly near the great meat-packing centers. The meat-packing centers for beef are, in the approximate order of their importance, Omaha, Chicago, Kansas City, St. Paul, and St. Louis. Smaller but still important centers are Sioux City, St. Joseph, Indianapolis, Fort Worth, Milwaukee, Denver, and Oklahoma City. These centers furnish the bulk of the meat supplies to the densely populated industrial districts farther east. Exports of beef and beef products are small, the trade with Hawaii, Puerto Rico, and Alaska surpassing that with foreign countries. In recent years imports of beef have surpassed exports.

South America. In both Argentina and Uruguay the beef industry is a dominating factor in the economic life. Originally the development of the cattle industry was favored by the enormous landholdings and by the nutritious grasses of the Pampa. The mild winters, which make grazing possible throughout the year, proved to be an important asset. At present the production of high-grade beef in Argentina is to a large extent dependent upon the growing of alfalfa, which is a valuable complement to the native grasses of the region. Because of their small populations, Argentina and Uruguay have large surpluses of animal products. Some of the low-grade beef, especially that from the neighboring Chaco, is made into meat extract and related products, but most of the beef prepared in the packing houses, or *frigorificos*, is high grade and is shipped in chilled condition to the great centers of consumption of western and southern Europe.

Australia and New Zealand. In Australia, there are about 10 million beef cattle compared to 10 or 11 times that number of sheep. However, cattle are much more widely distributed than sheep and are found not only in the sheep regions but also in the eastern coastal plains and in the tropical grasslands of northern Queensland, Northern Territory, and Western Australia. The coastal pastures of eastern Queensland are often in planted grasses, and supplementary feeds are frequently grown. The range cattle raised in the interior are brought to the coastal areas for fattening and processing.

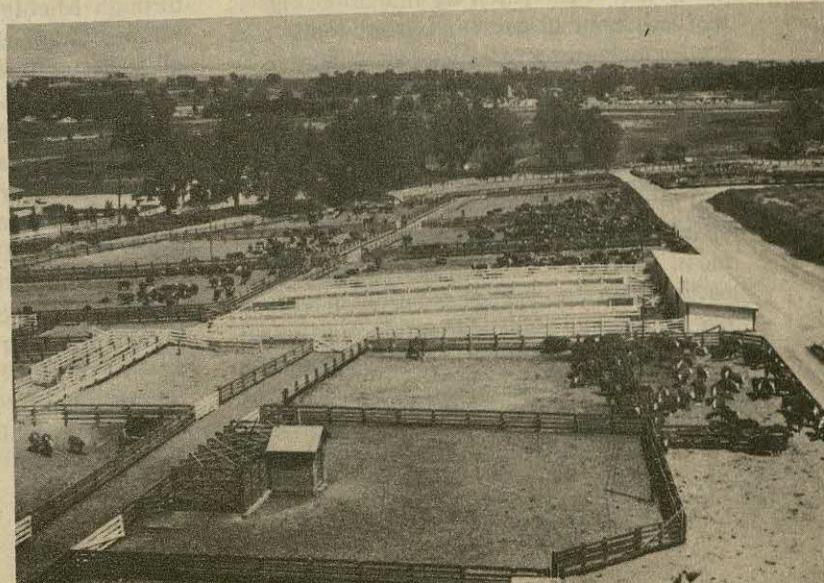


Fig. 181. A large, modern "feeder lot" in Colorado, just north of Denver.

Courtesy U.S. Department of Agriculture

Australia is sparsely populated and has a large surplus of animal products available for export. The country is, however, handicapped by its distance from the principal centers of consumption in Europe. Formerly, much of the meat was shipped frozen, because of the long voyage through the tropics, and brought appreciably lower prices than the chilled beef from the Río de la Plata countries. In recent decades, however, with improvement of cooling facilities, there has been a considerable increase in the shipments of chilled beef. New Zealand also is an important exporter of beef. There the cattle industry is concentrated primarily in the low coastal plains of North Island.

Europe. In most of Europe, north of the region of Mediterranean climate, cattle are numerous, but, with the exception of parts of Great Britain and Ireland and of some lesser regions, the raising of beef cattle is not an aim in itself: it is an integral part of a highly diversified system of agriculture. Beef cattle are usually surplus dairy or dual-purpose animals fattened by using locally produced grass, hay, or other roughage, supplemented by grains, oil cake, and other concentrates, large quantities of which must be imported. As a result of the dense population, few countries consistently have an exportable surplus of beef. On the whole, Europe is an area of meat deficiency and forms the principal market for all the meat-exporting countries of the world.

The localization of beef and dairy industries. Beef eaten by human beings is derived from grasses and from feeds and feed concentrates produced by tillage agriculture. There is considerable inefficiency in the conversion by cattle of these materials into meat. We can obtain much more food, measured in calories, from an acre of humid-zone cropland by direct production of edible crops than we can by producing meat. Therefore, in the crowded parts of the earth, where food supplies barely meet local needs, the more efficient production of edible crops rather than meat production must be emphasized. This is the case, for example, in Japan and China, where pressure of population upon the land is so great that practically all cropland is too expensive for the production of beef. Generally speaking, a beef-cattle industry can be successful only in regions where population is comparatively sparse and where land is cheap. The British Isles are one of the notable exceptions since Great Britain has been sufficiently wealthy to import large amounts of vegetable foods—and even additional quantities of meat—from abroad. In addition, part of the animal industry of Great Britain concerns itself with the breeding of high-grade strains.

Dairying is a more efficient form of animal industry than meat production and can be carried on where population is dense and land fairly expensive, provided that the conditions of the natural environment are favorable to dairy cows and that at least some natural humid pasture and hay land is available. In many of the more densely populated dairy areas, such as in the Netherlands and Denmark, considerable quantities of supplementary feedstuffs must be imported. Dairying is also a successful pursuit in areas of relatively sparse population where, because of climatic conditions, the land is better suited for the production of feed and feed grains than it is for that of wheat and other foodstuffs. Such is the case, for example, in parts of Wisconsin, northwestern France, and New Zealand.

THE UNITED STATES. In the United States the most favorable conditions for dairy farming are found in the Hay and Dairy Region, which stretches from Minnesota through Michigan and Ohio as far east as Maine. Grass and hay are abundant, and all sorts of feedstuffs can easily be grown. The entire area is advantageously located near the industrial regions of eastern United States. While dairymen in the states closest to the great urban centers, such as New York, Pennsylvania, New Jersey, and the states of New England, etc., devote most of their attention to the production of milk, in many instances shipped to the cities by special trains or tank trucks for bulk haulage, in the states farther west a large portion of the milk is manufactured into butter and cheese, which can stand some delay in shipment. The principal butter-producing

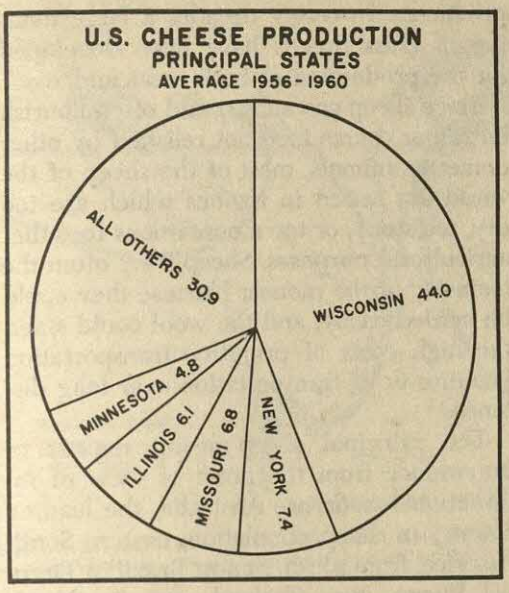


Figure 182.

states are Minnesota and Iowa. Other important producers are Nebraska, Missouri, Ohio, Michigan, Indiana, North Dakota, Illinois, and Kansas. Wisconsin makes nearly half the cheese of the nation (Fig. 182). Smaller dairying areas lie in the Puget Sound-Willamette lowland of western Washington and Oregon, and in California. In the dairying regions of the Northeast and of the Pacific coast states much milk is canned in condensed and evaporated form or reduced to dried or powdered milk. Considerable quantities of canned milk are exported to the Philippines, Panama, and other countries of Latin America and the Far East, which, because of a tropical or subtropical climate, produce little milk themselves.

EUROPE. In Europe the dairy industry is highly developed in the low-lying areas from Brittany to southern Sweden and in the British Isles. These regions are subject to the direct influence of the westerly winds, and thus have a mild and moist climate which fosters the growth of luxuriant grasses and the production of feedstuffs.

The best-known dairy districts are in Denmark and the Netherlands. In the latter, the dairy industry is based primarily upon the succulent grasses of the *polders*, the rich marine and alluvial lands which generally lie below sea level. The polders are surrounded by dikes, and the water table is regulated by modern pumping installations. Because of the high density of cattle per acre it is necessary to import large quantities of supplementary feed, such as barley, linseed cake, and cottonseed cake or meal. The Danish dairy industry is also highly intensive. It is dependent mainly upon feed crops, such as barley and artificial pastures of clover and hay. Furthermore, large quantities of feedstuffs, especially concentrates, are imported from abroad.

The success of the Netherlands and Danish dairy industries is largely due to the demands from the nearby industrial regions of Great Britain, Belgium, France, and Germany.

Other well-known dairy districts are the plateau and the Alps of Switzerland and the Po Valley of Italy. In Switzerland the high pastures above the timber line furnish excellent summer grazing. The principal center of dairy production, however, lies on the plateau along the northern foot of the Alps. France is noted for its many different types of cheese.

Denmark and the Netherlands rank first in the Northern Hemisphere as exporters of butter. The Netherlands is the largest exporter in the world of condensed, evaporated, and powdered milk, while the principal cheese exporters of Europe, in the order of their importance, are the Netherlands, Denmark, Switzerland, France, and Italy, all of which are noted for the excellence of their products.

NEW ZEALAND AND AUSTRALIA. In recent years New Zealand and Australia have developed an extensive dairy industry and have become major exporters of butter and cheese.

In Australia the dairy industry is most important in the more humid coastal districts of Victoria, New South Wales, and southeastern Queensland. In New Zealand the industry is carried on mainly in the coastal plains of North Island.

SWINE

Swine grow under widely varied types of environment. Some breeds of swine flourish in regions with distinctly tropical climates as, for example, in the Philippines and Indochina. Nevertheless, on a world map showing the distribution of swine, large areas will be found blank. This is not the result of a lack of statistical data but of the prevalence of religious taboos. Mohammedans, Hindus, and Jews are not allowed by the precepts of their religion to eat pork. Thus swine are scarce in India, the Near East, and most of northern and central Africa. The principal swine-raising regions are in countries of intermediate climate, especially in North America and Europe, although important production is also found in southern Brazil and China.

Distribution. In the United States the hog industry centers in the Corn Belt, where the raising of hogs on corn forms the foundation of the entire agricultural scheme. Hog processing is carried out in large meat-packing centers of the American Midwest. Chicago was formerly the principal center, but since 1950 the packing houses for hogs have dispersed to Omaha, St. Louis, South St. Paul, and Sioux City. Many smaller hog-packing centers are scattered throughout the entire Corn Belt.

In Europe swine are fed not only grains, especially barley and rye, but also potatoes and skimmed milk. Because of the latter the swine industry is often closely associated with the dairy industry, this being typical in Denmark and the Netherlands.

The principal exporters of pork and pork products are Denmark (bacon and pork) and the Netherlands (ham and bacon). United States exports of pork, bacon, ham, and canned pork products are small and go mostly to Caribbean America, South America, and Europe.

SHEEP

Some breeds of sheep, such as the Merinos and Rambouillets, are excellent wool producers, while others, such as the Lincolns and Shropshires, are primarily meat producers. In recent decades a large number of cross breeds have been developed for the production of both meat and wool.

Since sheep can subsist and often flourish on rather coarse feed not relished by other domestic animals, most of the sheep of the world are raised in regions which are too dry, too stony, or too mountainous for other agricultural purposes. Sheep were often the mainstay of the pioneer because they could be herded easily, and the wool could stand the high costs of primitive transportation facilities or of transportation over long distances.

The principal sheep-raising regions of importance from the point of view of international trade are Australia, the leading country in sheep population; eastern South America, from southernmost Brazil to Tierra del Fuego; New Zealand; and South Africa—all areas of relatively sparse population and with many square miles of humid to semiarid pasture. However, large numbers of sheep are also raised in the United States; in the semiarid lands of southern Russia; in the Near Eastern countries of Iran, Iraq, and Turkey; in Spain; and in Great Britain. In the most humid districts the mutton types predominate. In the dry lands, as in interior Australia, most of Patagonia, the high plateaus of South Africa, and the Spanish plateau, the wool-producing breeds are in the majority (Fig. 183).

In the mountainous districts of southeastern Europe, sheep do well on lands poorly suited to tillage agriculture. However, none of the countries of this part of Europe have an appreciable export surplus of either wool or meat.

Great Britain has an exceptionally large number of sheep, owing in part to the extent of poor grazing country and in part to the popularity of mutton in the British diet. Because of the dense population, however, there is a large deficiency of both meat and wool.

Sheep in the United States. In the United States sheep are most numerous in the semiarid and mountainous range country west of the Great Plains and on the Edwards Plateau of Texas. While formerly sheep of the wool-producing Merino and

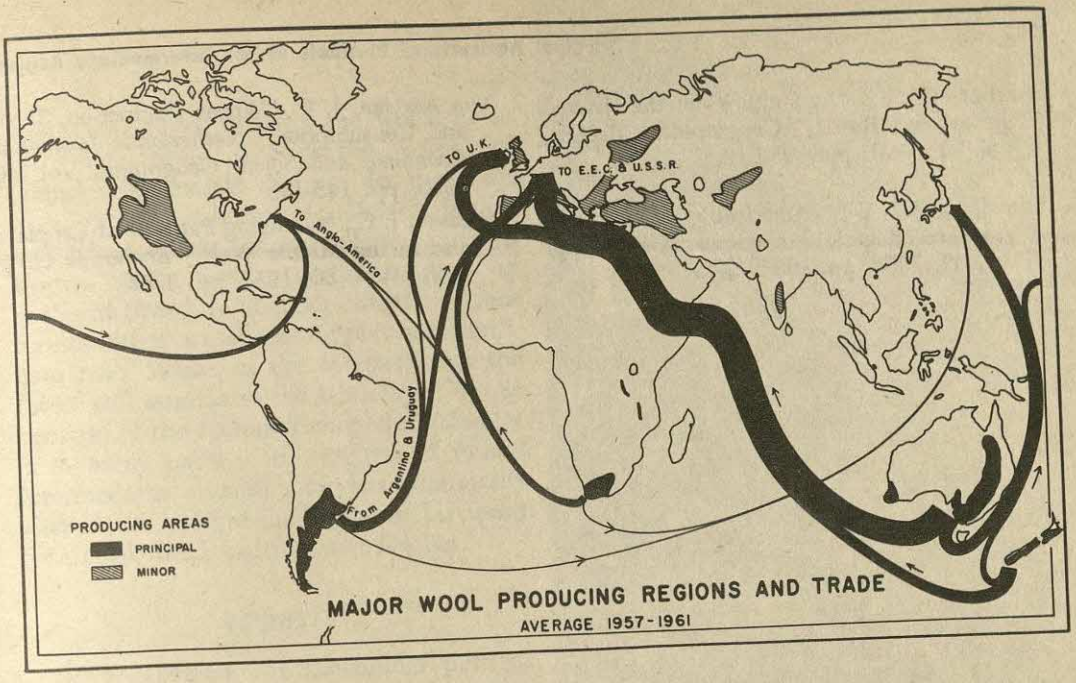


Figure 183.

Rambouillet types predominated in the United States, at present an ever-increasing percentage is raised primarily for meat, and even on the western ranges production for both meat and wool is favored. In the semi-arid ranching country of the West, sheep raising gives rise to regular migratory movements: from the winter grazing grounds in the desert areas to the high summer pastures of the mountains, most of which lie in the national forests. Production of early lambs is important in many parts of the ranching area. The principal fattening and finishing districts for lambs are the valleys of the North and South Platte rivers in Colorado, Wyoming, and Nebraska; the Snake river district of Idaho, and the Valley of California. The latter produces winter lambs. In the Corn Belt and the states farther east, sheep are less numerous.

International trade. The large exporting countries of wool and mutton all lie in the Southern Hemisphere: the Río de la Plata countries, South Africa, Australia, and New Zealand. The exports of mutton are mostly destined for the British Isles. The wool is exported to the countries which are important centers of manufacture of woolen goods, principally the United Kingdom, the United States, France, West Germany, Belgium, Italy, and Czechoslovakia. The Leeds-Bradford district in England is the leading woolen-manufacturing district of the world.

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16

Forests and Forest Industries in the Intermediate Regions

THE GREAT forest areas of the world lie in the rainy tropics and in the regions of humid intermediate climate. In the areas with humid subtropical climate important forest stands survive only in southern United States and in certain sections of southern Brazil. In all other climatic regions forests either are absent or play a subordinate role. While in the rainy tropics the forest still dominates the landscape, largely because of the factors discussed in Chapter 8, in many parts of the regions of humid intermediate climate man has profoundly altered the natural landscape in his quest for tillable land, pasture, and lumber.

FORESTS

Deforestation. In the milder portions of the intermediate regions more favorable for agricultural development, the once extensive forests of hardwoods, mixed hardwoods and conifers, or pure conifers have largely succumbed to the ax of the woodman and the farmer. In the United States even some areas that are marginal for agricultural purposes have been denuded of their stands of virgin timber. The most extensive deforested areas of the world lie in: (1) Europe south of a line which runs approximately from Oslo to Stockholm to Pskov, USSR, and from there to the Ural Mountains via Vologda and Vyatka; (2) Asia from southern Manchuria to southern China; (3) the United States east of the Mississippi, particularly in the fertile areas of Ohio, Indiana, southern Michigan, southern Wisconsin, in parts of Kentucky and Tennessee, in large portions of the Piedmont, and elsewhere. In these areas a cultural landscape consisting of tilled fields and pasturelands with scattered stands of timber has supplanted the original continuous forest cover. Only mountainous regions little adapted to agriculture or regions of poor, sandy soils still have extensive forest stands. Hardly any virgin timber is left in these regions, and in many countries, especially in those of western and central Europe, the stands have been created by man, are carefully protected, and so managed that sustained yields seem assured.

In the United States many of these stands are the result of natural growth after the land has been cut over one or more times. However, here also careful management is gaining ground.

The northern coniferous forests. Farther poleward, where short growing seasons and poor, often podzolic, soils hamper agricultural development but allow the growth of hardy conifers and a few types of deciduous trees, the forest still dominates the landscape. There, an immense belt of coniferous forests, which roughly coincides with the belt of subpolar climate, stretches across northern Eurasia and North America. In North America this belt is located mostly in Canada, but includes the northern half of Minnesota, portions of northern Wisconsin, much of northern Michigan, the Adirondacks of New York, and much of northeastern New England. Important southward extensions of coniferous forest are found in the mountains of Washington, Oregon, and California, in the Rocky Mountains as far south as New Mexico, in the Ural Mountains, and in eastern Asia. The only other extensive areas of coniferous forest are those of the southeastern states of the United States and the Paraná pine forests of southern Brazil (Fig. 63).

Along the southern fringes of the northern coniferous forests stands may be mixed, coniferous, or even deciduous. There conifers usually occupy the poorer soils and the higher lands with short growing seasons, and deciduous trees the more favored localities. Northward, toward the arctic tundra, the coniferous stands gradually become less dense and the trees smaller; areas of tundra vegetation or swamp vegetation become more frequent and more extensive, until finally only a few low and deformed trees survive in the most sheltered places. Thus, from a commercial point of view, the southern part of the main coniferous forest belt is of greater importance.

The forests consist mainly of relatively few types of coniferous or softwood trees, which generally appear in pure stands, this being markedly true of the pines and spruces. The principal trees of the northern coniferous forests are the spruces (*Picea*), firs (*Abies* and *Pseudotsuga*), pines (*Pinus*), tamaracks or larches (*Larix*), hemlocks (*Tsuga*), and cedars (*Thuja*). The more tolerant types of hardwoods, birch and poplar, occur especially near the southern margin, although some species extend far north. Poplar often flourishes where forest fires or indiscriminate cutting have destroyed the stands of conifers. In Canada, for example, burnt-over areas frequently carry an admixture of different types of poplar and birch, with jack pine on the poorer soils.

Not all of the northern belt is covered by forest vegetation. Northern Eurasia and northern North America both were heavily glaciated during the Pleistocene period. This resulted not only in poor, stony soils, but also in poor drainage. Although the annual precipitation is small, evaporation is retarded by the prevailing low temperatures, and in many areas downward movement of soil water is prevented by permanently frozen subsoil. Therefore, plenty of water is available for run-off. Because of the highly irregular glacial topography, however, much of the surface run-off collects in numerous lakes, swamps, and peatbogs. On the latter, tree growth is either absent or badly stunted, and such timber as exists is useless for commercial purposes. Thus, of the approximately 2,500 million acres of forest land in the Soviet Union, nearly 1,000 million are estimated as consisting of large bogs and other unproductive areas, the bulk of which are located in the subarctic belt. In Siberia only 38 per cent of the area classified as "forest area" actually carries stands of sufficient size and density to be referred to as forest. In northern Sweden it is estimated that peat bogs devoid of merchantable timber account for 30 per cent of the total area. In the northern coniferous area of Canada similar conditions exist.

LUMBERING

The lumber industry in much of the coniferous belt is carried on in a stern natural environment. Population is sparse, and agriculture can often survive only in close association with lumbering. Some of the factors which handicap agricultural develop-



Courtesy U.S. Forest Service

Fig. 184. River driving of logs on the Machias River in eastern Maine. Moving or "sluicing" of logs out of one of the lakes in the river.

ment are among the most valuable assets of the lumber industry, as for example, the long, cold winters and the persistence of a snow cover. Also advantageous to the industry are the spring freshets of the numerous rivers which result from the melting of the snow.

Cutting generally begins early in the fall, before the snow has become too deep. Where agricultural communities exist in proximity to the exploitations, for example, in Sweden, Finland, and Quebec, the farmer becomes a lumberjack for the winter season. Elsewhere, as in parts of Canada and northeastern European Russia, the labor must be imported, and lumbering often becomes a large-scale enterprise requiring heavy investment in capital goods. The snow facilitates dragging the logs to the streams by horses or tractors (usually of the caterpillar type). The logs are piled on the ice, and in the spring, when the melting of the ice and snow causes a brief period of high water, they are allowed to float down the rivers to a place where they can be sorted as to ownership and size and then processed in either a sawmill or pulp factory (Fig. 184).

In some regions, particularly in Sweden but also, for example, in northern New England, considerable amounts of capital have been invested in the improvement of these log-driving ways. Rapids and shoals are eliminated insofar as possible; rows of floating logs are anchored along the banks and in the bends of the streams; flumes are constructed to secure a most efficient use of the spring freshets.

In northern Russia log driving is handicapped because the majority of the rivers flow northward into the Arctic Ocean, and therefore the ice breaks up in the upper courses long before it does farther downstream. The floods which result may scatter the logs over the entire width of a valley. On the Pacific coast of North America, much of the timber is too large, and most of the streams are too swift and contain too many falls and rapids to make possible the use of this cheap method of transportation. Consequently, mechanical means of transportation must be used. Either donkey engines and cable traction are used, or the timber is "cat-logged," that is, dragged by caterpillar tractor to the nearest road or rail line. In many districts railroad systems, which may include narrow-gauge "feeders" and standard-gauge main lines, have been

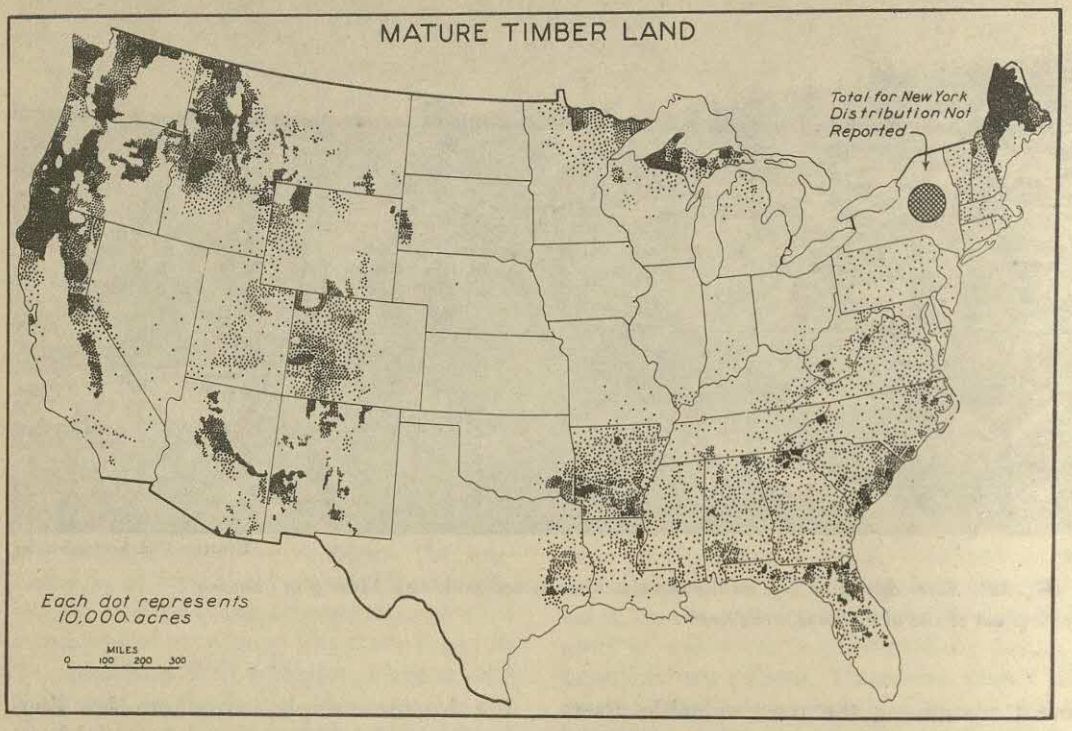


Fig. 185. Distribution of land supporting timber currently marketable for the major forest products. Does not include second-growth stands cut for minor products. (Published in Part VIII of the Supplementary Reports of the Land Planning Committee, National Resources Planning Board.)

built to transport the lumber to the coast. With such equipment lumbering may be carried on throughout the year.

Principal centers of forest exploitation. Lumbering is carried on mainly in accessible areas, relatively close to good transportation facilities. In Eurasia the principal centers of production for lumber and pulpwood are found in northern Sweden; Finland; northern European Russia, especially the respective hinterlands of Leningrad and Archangel, Karelia, the regions to the north and northeast of Moscow, and the central Ural area (the Perm and Sverdlovsk districts); and the Novosibirsk, Krasnoyarsk, Irkutsk, and Khabarovsk regions of Asiatic Russia. In Canada the provinces of British Columbia, Ontario, and Quebec have the largest annual timber cut.

Large parts of the northern coniferous forest belt in Siberia and western interior Canada are so far from the areas of consumption and have such poor transportation facilities that at present commercial exploitation is not feasible.

Timber resources and forest exploitation in the United States. In the United States the original immense resources of hardwoods and softwoods have been greatly depleted. This is partly because vast areas were cleared for agricultural use, a type of use which greatly increases the value of an acre of land. Unfortunately, much land unsuitable for agriculture was also completely stripped of trees by the lumber industry, and no healthy trees of sufficient size were left to start a slow process of natural restocking. In many cases what came back after "clean cutting" were tree species of lesser value. In the areas of coniferous forests especially, whatever trees were left by the lumberman were in many instances de-

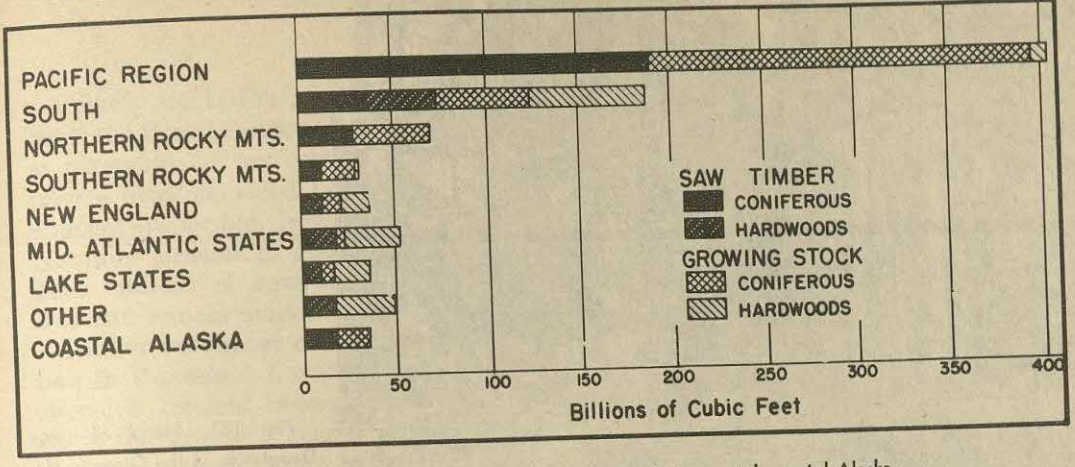


Fig. 186. Total stands of timber in the forest regions of the United States and coastal Alaska, 1953. (Source: Timber Resource Review, 1955, U.S. Forest Service.)

stroyed by fire, and hardwoods of low quality subsequently took the place of the valuable softwoods. It is estimated that in the United States forests of commercial value, both hardwoods and softwoods, originally covered an area of roughly 820 million acres. Today the acreage of old-growth saw timber—mature forests not seriously affected by fire or damaged by insects or diseases—is about 50 million acres, according to the United States Forest Service. The only areas where considerable stands of such timber still exist are the Cascades, the Sierra Nevada, the coastal ranges of Washington and Oregon, and the Rocky Mountains. The Pacific Northwest has about 17 million acres; the Rocky Mountains, 17 million; California, 11 million; and coastal Alaska, 4 million. However, half of the virgin stands in the Rocky Mountains and in California are of poor quality. Little virgin timber is left in the forested portions of New England, New York, and the Great Lakes states, and even in the Atlantic and Gulf coastal plains such stands now constitute only a very small percentage of the total forest area (Fig. 185).

Fortunately, a considerable acreage of second growth, over 130 million acres in all, has reached saw-timber size. *Saw timber* denotes merchantable trees which are large enough to yield logs for lumber. Their minimum size varies from 9 to 23 inches in diameter at breast height, depending upon species and region. Much of this young saw timber occurs in the South—60 million acres. Less than 50 million acres are located in the North, with the remainder in the West and in coastal Alaska (Fig. 186).

Besides these areas of merchantable saw timber there are approximately 170 million acres of *pole timber*, characterized by trees which are too small for saw logs but large enough for cordwood, and 95 million acres of small-dimension saplings and seedlings.

The forests of the Northwest and of California consist almost entirely of coniferous trees, among which the Douglas fir (*Pseudotsuga taxifolia*) and the western yellow pine (*Pinus ponderosa*) are of major importance (Fig. 187). The Pacific states are responsible for well over half of the production of coniferous saw timber of the United States. In parts of the West the annual drain exceeds annual growth. Excessive cutting of virgin stands, premature cutting of second-growth timber, heavy depletion due to fires and insect damage, and prevalence of conditions which hold back natural growth are largely responsible for this situation.

As a producer of all sizes of both softwoods and hardwoods, southern United States holds first place. The area occupied in the South by forest land rated as commercial is estimated at 193 million acres, or nearly 40 per cent of the total for the United States (Fig. 185). Practically all of the forest area consists of second-growth saw timber, pole timber (producing cordwood for



Fig. 187. Stand of large Douglas fir in the Olympic National Forest, Washington. A "feller" is beginning work with a one-man power saw on a large tree.

Courtesy U.S. Forest Service

pulp and other purposes), saplings, seedlings, and cutover areas. There is hardly any virgin timber. Available saw timber in the South is less than one third of what it is in the Pacific states. Formerly annual drain of saw timber and pole timber exceeded total net annual growth, but in recent years new growth has somewhat exceeded depletion. This is a fortunate turn of events, as in this region annual growth is greater than in any other part of the country and, therefore, it is here that it will be easiest to make up by natural growth for some of our timber losses. In the West annual growth is not as large as one might expect, judging by the acreage, since there are still large acreages of old timber which is beyond its period of vigorous growth. Much of the increase in saw timber in the South is due to southern yellow pine (*Pinus echinata*), a tree that encounters very favorable growing conditions throughout most of the area.

The timber situation in the United States, though it has shown improvement during recent decades, is still far from satisfactory. Total cut of timber probably continues to exceed slightly annual growth increment. This is true especially for the softwoods. Losses due to disease, insects, fire, and other causes are still high. If a comparatively young tree is killed by fire or disease, we lose not only the timber that is in the tree now, but also what growth would add to it during the next 10, 20, or more years. Thus the impact of such losses on future supply is much greater than are the losses themselves.

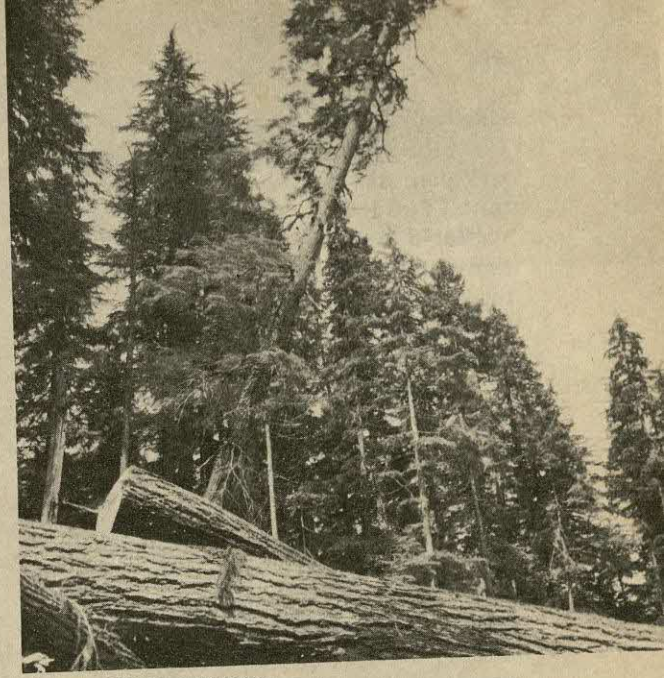
Better management of forests is slowly gaining ground, although the United States still is a long way from the over-all efficiency of forest management as practiced in many European countries. Of the total commercial forest land in the United States, a little over one fourth is owned by the federal government, or by state, county, or municipal governments. Most of these forest lands are comparatively well managed. Part of the private forest land is also well managed, but much further improvement is needed. Some of these private lands are owned by corporations engaged in forest industries. Such corporations account for half of one per cent of all the owners, holding about 13 per cent of the commercial, privately owned forest land. A number of other owners hold properties ranging in size from 5,000 to 50,000 acres. The remainder is mostly owned by farmers in comparatively small lots, together accounting for 35 per cent of the total.

The commercial forest acreage in the United States is probably about 480 million acres, but of this well over 100 million acres

are poorly stocked or nonstocked. Of these lands the Forest Service classifies 52 million as plantable, 83 per cent of which are in private ownership and 17 per cent in government ownership. New annual plantings generally amount to about 600,000 acres. Thus millions of acres of potential forest land still remain unused.

Timber resources and forest exploitation in Canada. Canada, except for the extensive treeless tundra regions of the north, the Prairie Provinces in the central west, and a small region of original hardwood forests in southernmost Ontario, lies within the great northern coniferous belt in which hardwoods play a subordinate role (Fig. 63).

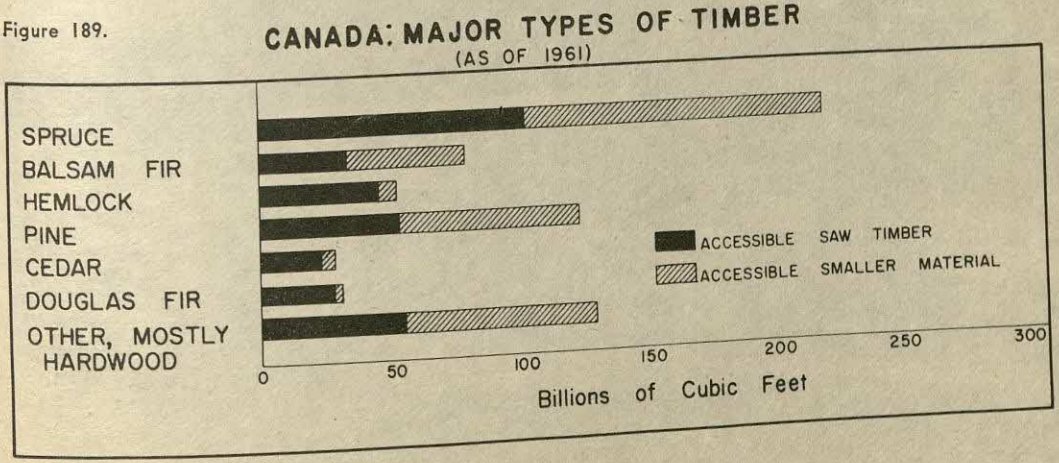
It is estimated that Canada possesses 1,712,000 square miles of forested land. Unfortunately, a large portion of this land, probably 42 per cent, is nonproductive and will probably never be productive because natural conditions are so unfavorable that the trees do not grow to merchantable dimensions. This leaves a total area of nearly one million square miles of productive stands. However, many of these productive stands cannot now be reached for purposes of exploitation. As accessible are rated 725,000 square miles of timber. The acreage of accessible saw timber is located especially in British Columbia, followed at a considerable distance by Ontario and Alberta, with stands of smaller extent in the other provinces. The major producers of lumber are British Columbia, Ontario, and Quebec. The principal coniferous species cut are spruces and balsam fir (*Albies balsamea*), Douglas fir, hemlocks, and white and red pines (*Pinus strobus, Pinus monticola, a.o.*), with smaller quantities of cedars, jack pine (*Pinus divaricata*), and lodgepole pine (*Pinus contorta*). Among the hardwoods, birch and maple are most important, though hardwood production usually constitutes only a little over five per cent of total lumber production. The largest accessible reserves of saw timber consist of spruce and balsam fir, chiefly in British Columbia, Ontario, and Quebec; hemlock,



Courtesy U.S. Forest Service

Fig. 188. Large Douglas fir tree topples. Gifford Pinchot National Forest, Washington.

Figure 189.



chiefly in British Columbia; cedar in British Columbia; Douglas fir in British Columbia; jack pine and lodgepole pine mostly in Ontario (Fig. 189).

World lumber trade. The bulk of the timber cut in the middle latitudes is used for lumber and fuel, and smaller quantities are used for pulpwood, veneer logs, hewn ties, fence posts, mine timbers, shingles, and other purposes. In the majority of the countries located in the intermediate and subtropical climatic regions, consumption exceeds production, and large imports are necessary. This is especially true in Europe. For example, in Great Britain only 5 per cent of the land area is in forest; in the Netherlands, 7 per cent; and in Belgium, France, and Italy, about 18 per cent. All of these countries are heavy importers. Germany ranked as the second major European importer before World War II. This condition gives rise to an important trade in wood and wood products. As softwoods are easily workable and suitable for many purposes, they are in great demand all over the world. The principal exporters of wood and wood products are those countries which have a share of the great subarctic belt of coniferous forests: Canada, Sweden, Finland, the USSR, and the United States. However, the United States now imports from six to seven times as much lumber and wood products as it exports.

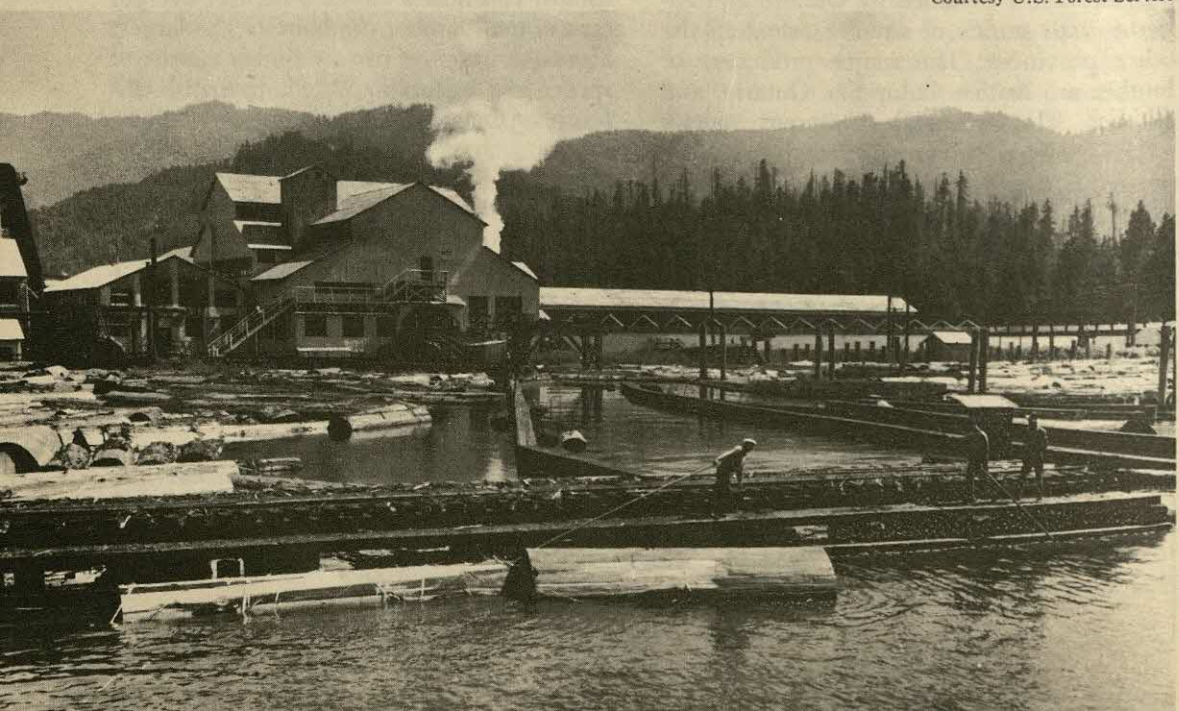
While in the past most of the timber entered world trade as roughly hewn logs, now it is generally shipped as lumber. Some producers export even semimanufactured and finished products, such as plywood, roof shingles, doors, and window frames.

WOOD PULP AND PAPER

During the last half century the paper industry has become an important consumer of wood, since most of the paper now used in the world is made of wood fiber. As a result of the lower cost of manufacturing paper stock and in response to the greatly increased output of books, magazines, and especially of newspapers, the requirements of the paper industry have grown enormously. The rayon industry uses wood pulp, and the plastics, cellophane, fiberboard, and related industries use increasing quantities of wood pulp and wood waste. For the manufacture of wood pulp, trees smaller than saw-timber size (pole timber) can be used. This gives a greater measure of eco-

Fig. 190. A redwood saw mill in California. Note the diameter of the logs.

Courtesy U.S. Forest Service



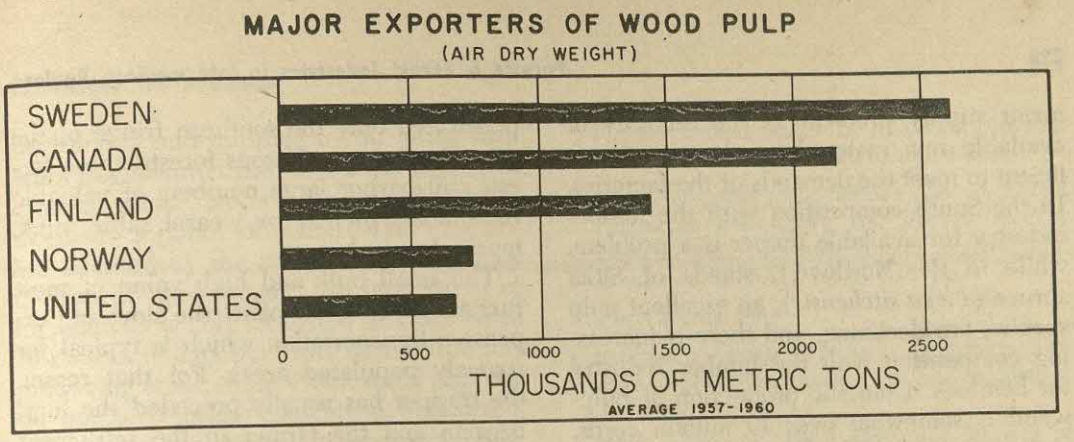


Figure 191.

nomic security to pulpwood plants than to the ordinary sawmill enterprises because under careful management suitable timber can be maintained within reach of the plant.

Soft coniferous woods, low in resin, such as various kinds of spruce, balsam fir, and hemlock, are preferred for the manufacture of pulp for papermaking. In recent years manufacturing processes have been improved to such an extent that the number of usable species has increased greatly. Southern yellow pine is now one of the major sources of pulpwood in the United States. Poplars, jack pines, white fir (*Abies concolor*), beeches, birches, and maples are other species in current use.

The wood is reduced to pulp either by purely mechanical means or by cooking under steam pressure and with an admixture of chemicals. The first method produces mechanical pulp, the second various kinds of chemical pulp, such as sulfite and sulfate pulp. All of the newsprint and other cheap grades of paper, which do not need to be of great strength or of pure white color, are manufactured from mechanical pulp, though usually with an addition of sulfite pulp. The chemical processes eliminate a large part of the lignin or wood substance, leaving mostly cellulose. They are more expensive than the mechanical processes and yield smaller amounts of pulp, which is, however, of longer fiber and easier to bleach. The sulfite process, which consumes chiefly spruce and hemlock, is used for the better grades of paper, for example, book or magazine paper. The sulfate process is employed for the production of strong brown wrapping or kraft papers from resinous woods such as that of longleaf or southern yellow pine (*Pinus palustris*). The soda process is applied to hardwoods, such as aspen (types of *Populus*, or poplar) and yellow poplar (also called white wood or tulip tree, not a real poplar, *Liriodendron tulipifera*). Soda pulp is generally mixed with sulfite pulp for the production of medium and better-grade papers. In the United States mechanical and sulfite pulp constitute two thirds of the total requirements.

Pulp production. The pulp industry depends not only upon large amounts of cheap woods but also upon the availability of cheap power. Thus, the industry is located mainly along the southern edge of the coniferous forest belt in North America, near the coasts of Sweden, Finland, and Norway, and in the northern part of the Soviet Union, where raw material is abundant and where water power can be easily developed because of the glacial topography. The principal producers of wood pulp are the United States, Canada, Sweden, Finland, the USSR, and Norway. Major exporters are Canada, Sweden, and Finland (Fig. 191).

At present, pulpwood constitutes nearly one fourth of the cut of all timber products in the United States. The principal pulpwood-producing regions are the South and the Pacific Northwest, followed at a considerable distance by New England, especially northern Maine, and the Great Lakes states. Manufacturing plants in the older producing regions (New England, Middle Atlantic, and Great Lakes) face a

major supply problem as the quantity of available raw material has become insufficient to meet the demands of the factories. In the South competition with the lumber industry for available timber is a problem, while in the Northwest, stands of Sitka spruce (*Picea sitchensis*), an excellent pulp species, are declining, and there is increasing competition with the lumber industry for hemlock. Domestic production of pulpwood is somewhat over 40 million cords, and imports, mostly from Canada, range from 1 to 1½ million cords. Imports of newsprint paper from Canada are also quite large. In Canada about one third of the cut of all timber products is pulpwood. The provinces of Quebec and Ontario rank first as pulp and paper producers, but the industry has also established itself on the west coast, near the extensive forests of British Columbia. Smaller quantities are produced in Newfoundland, Nova Scotia, New Brunswick, and Manitoba.

While large quantities of wood are still available, both in the more accessible and in the less accessible parts of the northern coniferous belt, the rapid depletion of the virgin stands in several regions will make it urgently necessary to inaugurate everywhere policies of forest conservation such as are now practiced in, for example, Sweden and Finland. This is desirable not only because the wood consumption of the world is increasing steadily, but also because on much of the land under coniferous forest, timber is the only profitable crop.

FURS

The northern coniferous forests are the abode of numerous fur-bearing animals, varying in size from weasel to bear. The hunting and trapping of these animals provide a welcome source of cash income in many regions where returns from agriculture are small. Farther poleward they develop into an industry to which the population may devote much of its time.

In general, the longer and colder the winters are, the better is the quality of the fur. Inasmuch as agricultural settlement, with its attendant depletion of wildlife, has penetrated only the southern fringe of the great northern coniferous forests, these forests still harbor large numbers of valuable fur animals, such as fox, weasel, sable, mink, muskrat, and beaver.

The small bulk and high value of most furs are sufficient to offset the slow and expensive transportation which is typical for sparsely populated areas. For that reason the trapper has usually preceded the lumberman and the farmer in the settlement of forested territory. The role which the fur trade played in the establishment of British dominion over North America is well-known, but the significance of the same trade in extending Russian influence in Asia is not so well-known. The early expansion of the Russian empire from the Urals to the shores of the Pacific, and at one time even into Alaska, was due largely to the eastward and northward advance of the trapper in the trackless wilderness of Siberia.

Principal fur-producing countries. The Soviet Union is undoubtedly the largest producer of raw furs in the world. Although the domestic consumption is high because of the severe winters, furs have nevertheless always been important as an export item. Canada likewise is a major producer and exporter of furs. The provinces of Quebec and Ontario and the Northwest Territories usually lead in value of produced pelts. In many sections of the northern forest region the outposts of the Hudson's Bay Company are still the only nuclei of settlement. Among other fur-producing regions should be mentioned Mongolia, Manchuria, and northern China.

The United States not only produces much raw fur but, as a result of the high standards of living, is the principal fur-consuming country in the world. The value of the imports generally far exceeds that of the domestic production. As settlement spread in the United States, and more and more of the forest was turned into agricultural land or was destroyed by the lumber industry, the number of valuable fur animals greatly decreased. Where the Indian had been accustomed to carefully husbanding the resources of wildlife on his hunting grounds,

the hunting and trapping by the white man often degenerated into a process of virtual extermination. Nevertheless, and thanks mostly to a policy of conservation of wildlife adopted by the states and fostered by the federal government, the total catch of fur animals is still estimated at from 40 to 70 million dollars per year. Among the fur-producing areas, those which stand high are the northern states of Michigan, Wisconsin, and Minnesota; the central states of Ohio, Pennsylvania, and Indiana; and the southern state of Louisiana. St. Louis is a large fur-collecting center, and New York City ranks as a great world market.

Fur farming. As a result of the gradual retreat of wildlife before the advance of the white man and the increasing popularity of fur clothing, it has become profitable to raise certain kinds of fur animals, especially silver fox. Fur farming is practiced extensively in northern United States from New England to the Pacific coast. In southern Canada it has also become an important industry in all provinces, but especially in Ontario, Manitoba, and British Columbia. The practice has likewise been introduced successfully into several European countries.

Rabbits are raised in many countries, both for skins and for meat. The skins, which by various processes of manufacture can be made to resemble more expensive furs, play an important role in the international fur trade, Australia being the foremost exporter of this commodity.

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17

The Regions of Polar Climates

areas of limited potentials

BEYOND THE middle latitudes winters expand to include all or most of the year; ice and snow grip both the land and the ocean. In the areas of polar climates the average temperature of the warmest month remains below 50°F., and freezing temperatures may occur even during the brief period of warmer weather. The summers, though occasionally bringing warm, and sometimes even hot, days, are so short that their influence is entirely overshadowed by that of the long unbroken winter. The bleakness betokened by ice and snow is the predominant aspect of the landscape. However, it must not be thought that the white of ice and snow and the black of rock are the only colors of the winter landscape. There may be a surprising variety of color—from delicate pinkish and purplish shades to the bright green of some of the ice, particularly of the submerged parts of the icebergs that are visible when one flies. Even exposed rocks may show brighter colors.

The prevailing low temperatures, aided, perhaps, by occasional very strong winds, prevent the growth of trees. Although during the brief summer the upper soil may thaw out to a depth of one to three feet, the subsoil remains frozen throughout the year. This is the so-called *permafrost* or *merzlota*, as it is called by the Russians, the existence of which causes serious construction problems for buildings, roads, and railroads. Most of the precipitation falls as snow and, measured in inches of water, is so small that the polar regions would be semiarid if the temperatures were higher and there were more evaporation. Two principal types of climate can be recognized: the *tundra* type, characterized by a short summer which makes possible the growth of low vegetation; and the *icecap* type, where the ground is never free of snow and ice, and the higher forms of vegetation are entirely absent (see World Map of Climatic Regions).

THE TUNDRA CLIMATE

The tundra climate is extensive in the Northern Hemisphere, but in the Antarctic it occurs only on a few small islands scat-

tered through the southern part of the oceans.

The word tundra is said to be derived from the Finnish *tunturi*, which means a flat, barren plateau. In usage, the meaning of the word has gradually broadened and is now applied to treeless, steppelike areas covered with a vegetation of mosses and lichens, a vegetation characteristic of extensive areas in Alaska and Siberia. The term tundra is used here not as the name of a vegetation formation, but as the name of a climatic type. In fact, by no means all of the areas where this type of climate prevails carry only a vegetation of mosses. Grasses, sedges, and low-flowering plants occur in many places, so that during the brief summer period the land may be bright with flowers. In other places again may grow tree species, but in dwarfed form and with branches lying flat on the ground. Willow, alder, and juniper species, for example, may occur in this manner. Thus the tundra region, even though it may appear monotonous because of the lack of taller vegetation, shows a surprising and often useful variety to the observant traveler and to the inhabitant (Fig. 192).

The tundra, as a climate type, includes all areas where the average temperature of the warmest month is below 50°F. but above freezing (32°F.). It forms a belt of varying width that surrounds the Arctic Ocean, stretching over nearly 10 degrees of latitude in the eastern Barren Grounds of Canada and in extreme northeastern Asia. The total land area included is vast, being variously estimated at from three to five million square miles. The shores of the Arctic Ocean constitute the northern margin of the tundra. Its southern margin may project far southward in upland regions and recede far northward in the major stream valleys. In North America the tundra extends from northern Alaska to northern Labrador, including the Barren Grounds northwest of Hudson Bay.

Climatic conditions. Winter, the dominant season, is a period of darkness as well as of cold. In the southern parts the sun shines but two or three hours a day during midwinter, and in the northern parts it does not appear above the horizon for several weeks. Temperatures of −40°F. are common, and often they fall still lower. The snowfall, though not heavy, blankets the frozen ground. On the other hand, summers are short and featured by almost continuous sunlight, and in some of the more continental areas temperatures mount to unexpected heights. Summer maxima above 80°F. often occur where in winter the temperatures drop to −60°F. or lower.

Even greater extremes may occur from time to time, as, for example, at Fort Good Hope in northern Canada, where summer maxima of 95°F. and winter minima of −79°F. have been recorded. Spring may not come until June, and then only as a brief



Fig. 192. Tundra in Alaska. Note swampy conditions, and boat being towed along small channel. The men are wearing mosquito nets to protect themselves from insects.

Courtesy Alaskan Branch, U.S. Geological Survey

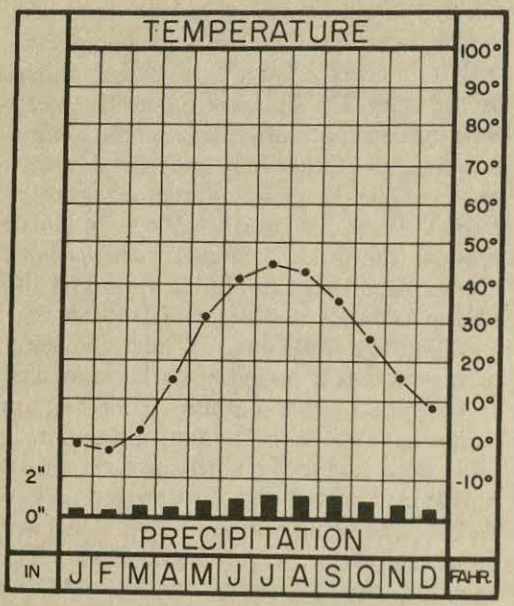


Fig. 193. Tundra climate. Average temperature and precipitation, Jacobshavn, Greenland. Altitude 40 feet, total precipitation 9 inches.

transition period from winter cold to summer warmth. Autumn is an equally short period, in late August or early September, when flowers disappear, and cold blasts introduce the long winter. Spring and autumn are so brief and temperatures so variable that they bear little resemblance to their counterparts in the middle latitudes.

Most of the precipitation falls as rain or snow in summer or early autumn, when daytime temperatures are generally well above the freezing point. Although not heavy, often averaging less than 10 inches during the year, most of the precipitation becomes soil moisture because of the levelness of most of the lands involved and the low rate of evaporation. During much of the summer the relative humidity is high, 70 per cent or more, and thick fogs are characteristic of the early part of this season in most of the coastal areas and often far inland (Fig. 193).

The long summer days, with continuous sunshine for weeks, as is the case beyond latitude 68°, constitute a period of weather which people of lower latitudes usually do not associate with polar climates. Sunshine uninterrupted except by occasional clouds, temperatures warm enough to be pleasant, a landscape verdure-clad and in the more favorable spots flower-bedecked, characterize the midsummer weeks. This season is so short that at its height people begrudge themselves the time for sleep. And then the long polar winter comes. Although the winter is a period of intense cold, raging storms, and great hardships for man, it is not without its compensating features. Along the southern margins brilliant moonlight at times dispels the darkness of the sunless days. At that season, also, the aurora reaches its maximum brilliance. At times, on crystal-clear nights, the whole sky is covered with surging waves of color; bands of green and blue and purple and pink go shooting, rolling, twisting across the heavens in a display of changing brightness never the same for two successive seconds. Only in the high latitudes can one find such superb celestial beauty.

Resources. The best-known resources are based on the natural vegetation. The tundra is the land of the reindeer and the musk ox and, during the warm season, the home of myriad birds and insects. The bordering seas are the habitat of seal, walrus, whale, and many kinds of fish. The human economy is based upon the utilization of animal life and, to a lesser extent, of plant life, because no tillage agriculture is possible.

With the passing of the winter snows, vegetation surges into life as though to make the most of the short summer season. Where the snow cover serves as a protecting blanket against intense cold, the vegetation is fairly profuse, while windswept places support but sparse growths. In swampy areas, caused by permafrost and inadequate surface drainage, water-saturated spongy mosses abound; in the drier places, various kinds of lichens and reindeer moss cover the ground and even grow on the surfaces of naked rock. In some of the more sheltered and better-drained lowland areas occur the arctic "prairies," consisting of herbaceous vegetation and grasses.

The drier parts of the tundra are capable of serving as grazing grounds for large num-

bers of meat animals, such as the reindeer, the caribou, and the musk ox.

These far northern areas are not without minerals, but difficulties of exploitation and transportation are great, and only the most favorable circumstances—highly valuable minerals of small bulk or nearness to possible water transportation part of the year—permit commercial production. Pitchblende, a source of uranium and radium, is mined on the edge of the Barren Grounds of Canada near Port Radium on Great Bear Lake. Cryolite, a mineral used in the refining of aluminum, has been mined in Greenland, and coal is produced on the coast of Spitsbergen (Svalbard) at nearly 80° N. latitude.

Human activities. The human population of the tundra is sparse. These regions are at the poleward limits of the higher forms of life, and the struggle for existence is intense and hazardous. The native peoples include such groups as the Eskimos of North America and the Lapps, Samoyeds, Yukaghir, and Chukchi of Eurasia.

A surprisingly varied set of cultures has been developed by the native peoples in the fairly uniform environment of the various tundra areas. Although animal products are everywhere the principal source of food, the Eskimos are hunters and fishers, depending upon sea mammals, such as seals and whales, and upon fish and caribou (Fig. 194); the Tierra del Fuegians in southern South America were more primitive fishers and hunters (at present only a handful of Ona, Yámana or Yahgan, and Alacaluf are left, and their mode of life has changed greatly); the Lapps and Samoyeds of northern Europe are dairymen, using domesticated reindeer; while the tribes of northern Siberia are herdsmen, raising great herds of semidomesticated reindeer for meat rather than milk. In like manner the snow igloo or the stone or sod house of the Eskimo is radically different from the large skin house of the northern Asiatics or the crude windbreaks and huts of the Fuegians. In land transportation the Eskimos use dog sleds; the Fuegians, who lived mostly on the water and along the shore, used their own backs; the Lapps and others, use reindeer-drawn sleighs; and the Siberians, reindeer back-



Courtesy American Museum of Natural History, New York

Fig. 194. Eskimo woman fishing through the ice. Model in American Museum of Natural History.

packing. Thus even the sternest environment offers man some choices, of which he avails himself according to his traditional background and his inventiveness. In other words, while the natural environment may influence what man does, or may set limits to what is practical for him to do, it is far from determining rigidly what he can or cannot do, and how he does it. There never really have been many adherents of "geographic determinism" among the geographers of the world.

Dependence upon the resources of the sea varies widely. Most of the inhabitants of the Eurasian tundra region are inland dwellers; in the autumn they withdraw to the forest, where they can find shelter to protect their herds from the blizzards. Their mainstay of economic life, the domesticated reindeer, can use the tundra forage and provide its owners with materials for food, clothing, and shelter. The Lapps and the Siberian peoples of the tundra are nomadic; they live in tents throughout the year, only a few tribes having more permanent habitations. Their migrations and mode of life are adjusted to the requirements of their herds, and these in turn are in accord with the

nature of the country. Since the most extensive pastures, those of reindeer moss, grow slowly and require several years to recover from overgrazing, the herds must continually be kept moving. In winter these peoples migrate southward, in summer northward, seasonally seeking the areas where forage is most readily accessible and, so far as possible, avoiding winter coastal storms and summer insect enemies which might decimate or annoy the herds.

The Eskimos, generally coastal dwellers, depend more directly upon the sea. They have become skillful hunters and fishermen. They are recognized as being among the most adept people in the world in handling their skin-covered, decked canoes or kayaks. In west Greenland the Eskimos have become distinctly sedentary, but in the northern part of Canada many of them retain their nomadic habits. There in winter they concentrate in larger settlements, while for the summer caribou hunting they disperse over wide areas.

Western civilization is represented in the tundra chiefly at "gateway" settlements such as Churchill, Canada, and Murmansk, USSR.

Economic significance of the tundra. Although not equaling the subpolar regions, the tundra has long been of some importance as a source of fine furs. Thousands of sable and blue-fox furs are marketed every year from these areas in Canada and Siberia.

As a resource amenable to exploitation in the distant future, the tundra pasturelands must be given some rank. Areas of considerable extent are available for reindeer grazing. Since these animals survive without feeding or prepared shelter, the production costs are low. While there is little prospect of the industry becoming of great commercial significance in the near future, it has promise as a possible source of additional meat when pressure upon the land to produce the necessities of life has become greater. As cultivable lands must be used more and more for crop agriculture, even extensive grazing lands such as the tundra areas will become of increasing importance for production of meat animals. (See Fig. 195.)

THE ICECAP CLIMATE

In the areas of icecap climate, year-round cold reigns supreme. The average temperature of the warmest month is below 32°F. Until recently statistical data concerning this type of climate have been rather fragmentary, but the vast amount of research that has been carried on in both the antarctic regions and in Greenland during the last decade have greatly added to our knowledge of temperatures, precipitation, and other climatic factors.

The icecap climate dominates interior Greenland, the Arctic Ocean, and Antarctica. These regions long have challenged the



Fig. 195. Reindeer team.

Photo by Mrs. Waldheim

imagination and adventurous spirit of man. Associated with them are the names of a host of men unafraid of the hazards of the unknown. Among those whose exploits have been truly heroic are Franklin, Greely, Nordenskjöld, Nansen, Scott, Shackleton, Peary, Amundsen, Wilkins, Papanin, Stefansson, and Byrd. Many other names merit a place in any honor list, but the above mentioned are outstanding.

The question is often raised as to why men face the hardships and dangers of polar exploration. The icecap regions are cold and hostile: there is virtually no plant or animal life, except along the margins. Although lands for settlement cannot be expected as a reward for new discoveries and explorations in the polar regions, and perhaps other economic rewards are likewise remote, any explorations are justified that push back the veil of ignorance. Man seeks to know all parts of the world regardless of economic benefits. The ideal that knowledge is worthwhile for its own sake has been dominant in nearly all polar expeditions. Since aviation has become a practical means of transportation and trade, interest in the north polar areas has increased because their location in respect to air routes has added an economic motive to the zeal of explorers. But the lure of the unknown and the special fascination of polar landscapes have been dominant incentives of individual explorers.

In recent years, scientific thought has been directed to the polar regions because of the effects of these areas upon world weather. Many scientists believe that when we know more about the meteorological conditions in polar areas we will have additional basic data for interpreting and forecasting the weather in the middle latitudes. Especially it is thought that a knowledge of the sequences of weather conditions over the polar icecaps might improve long-range forecasts of the weather in the agricultural lands of the intermediate climates. Thus further knowledge of conditions within the polar regions is apt to be of practical value as well. In view of the varied interests of adventure, air navigation, meteorological and other research, the polar regions bid fair to remain in the limelight of exploration for years to come. The poles have been reached, but vast areas still unseen or seen only cursorily serve as a challenge to the zeal to know, a zeal which constitutes one of the finest attributes of man.

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18

The Economic Significance of the Sea

present and potential

For centuries the sea has provided man with food, acted as a barrier to communication and, at the same time, been a means of transportation. Today the sea is becoming significant as a source of mineral wealth and of power, but, despite these other functions, fish remains its most important resource, and fishing one of the most important economic activities associated with the sea.

DISTRIBUTION OF MARINE LIFE

There is great diversity in both the nature and distribution of plant and animal life in the sea. Numerous species of microorganisms and macroorganisms belonging to both the plant and animal kingdoms live in varying densities and at varying depths in all parts of the ocean. Fundamental to the distributional pattern of the higher forms of life is the presence or absence of food. The basic food supply in the sea is *plankton*, which consists of many kinds of small to microscopic simple-structured plants and animals. Plankton can be divided into *phytoplankton*, or drifting organisms of a plant nature, and *zooplankton*, or drifting organisms of an animal nature. The productivity of phytoplankton depends on a number of factors, most important of which is the sun. Sunlight is the source of energy for the photosynthesis performed by the phytoplankton, and, since light penetrates to about 600 feet at the most, live plankton is confined to the surface layer of the ocean. This sunlit layer of organic activity is also known as the *euphotic zone*, and its depth depends on the inclination of the sun's rays and the clarity of the water. Zooplankton can exist at greater depths by feeding on dead phytoplankton which sinks from the surface layer, but, in general, the density of living organisms decreases rapidly with increasing depth. Development of phytoplankton also depends on the presence of gases and nutrient salts, of which carbon dioxide among the gases and phosphates and nitrates among the salts are of greatest importance. Phytoplankton occurs, therefore, most abundantly where water upwells, bringing to the surface nutrients which accumulated at depth.

Some of the decaying organic matter sinks well below the euphotic zone before it can be used by live plankton, and the gases and salts in solution which result from the decay may concentrate hundreds of feet below the surface. In some areas, for example, the phosphate content at 3,000 feet is 10 times that at 300 feet. Such a rich supply of nutrients cannot be utilized by the phytoplankton unless these nutrients are brought to the surface again, and this only occurs where conditions are suitable for vertical movement of water. For example, along some stretches of west coasts offshore winds prevail and tend to blow surface layers oceanward, thus allowing waters with a higher mineral content to rise from below near the shore. Similarly, between latitudes 50° and 60° S., and to a lesser extent in the North Atlantic and the Pacific Oceans, water that upwells in zones of convergence can support high densities of plankton. The other major areas of phytoplankton development are the waters over the continental shelves. Not only do additional supplies of nutrients come from rivers discharging into the sea, but, owing to the shallowness of the water, nutrients cannot sink out of the zone of organic activity.

The mid-ocean areas, particularly the tropical regions, have a much lower density of plankton, mainly because of the lack of vertical movement of water. Warm water remains at the surface, the organic material sinks, and the products of its decay concentrate at depth, finally moving away slowly in a latitudinal direction. Despite the greater intensity of sunlight in the tropics, lack of minerals limits the development of phytoplankton, and the average number of organisms per litre of water is only somewhere around 5,000 compared with around 100,000 in the waters of the mid-latitude continental shelves.

In intensely cold water the development of plankton is slowed down, but otherwise temperatures are not a significant factor in plankton distribution. Most varieties of fish, on the other hand, seem to be very sensitive to changes of water temperature and function best within ranges of a few degrees. Only slight variations of temperature appear to govern the migration of some species.

The degree of salinity of the ocean is known to be locally important to some species of fish.

DISTRIBUTION AND USE OF FISH

Many species of fish feed directly on plankton, but others feed on small fish which in turn feed on plankton. Tuna and salmon, for example, prey on other fish, but most species of whales, the world's largest mammals, are dependent on a variety of plankton, called *krill*, for their food supply.

The distribution of fish is similar to that of the plankton. The greatest densities occur over the continental shelves of the mid-latitudes, and it is here, too, that the greatest concentrations of single species appear. The tropical waters are characterized not only by a much lower density of fish population but also by a much greater variety of fish species.

The sea covers 70 per cent of the earth's surface, yet provides only 3 per cent of the world's food, though not all the fish caught are eaten. About half the estimated annual catch of 30 million tons is for human consumption, and another 15 per cent is used as animal food. Meal and fertilizer are processed from 25 per cent of the remainder, and a further 10 per cent is converted into fats and oils.

For many of the rice-consuming countries of the Far East, fish is the major source of animal protein, and in Northern Hemisphere areas such as Scotland and Norway, where agricultural land is in short supply, fish has always been an important item in the diet. Although the United States has the third largest catch in the world, after Japan and China, this catch is distributed among the country's large population, so that the per capita consumption of fish is only one tenth that of meat.

TYPES AND METHODS OF FISHING

Fishing is still primarily at the hunting and collecting stage of economic organization. Only recently has there been any at-

tempt to conserve or replenish resources. Economic and physical conditions limit the amount of fish it is possible to catch: some areas are difficult of access or too distant from markets, others are overfished or the fishing is fraught with political difficulties. Relatively few of the 20,000 or so species of fish in the sea are caught for domestic or industrial consumption, and only about 50 species occur concentrated in sufficient numbers and have sufficient market value to make large-scale commercial exploitation worthwhile.

There are two major types of fish: the *pelagic* and the *demersal*. Pelagic fish spend most of their time swimming at, or near, the surface of the water and include such species as herring, tuna, and menhaden. Demersal fish live near the seabed, and included in this group are both quick-moving fish, like the cod, and the more passive flat fish, such as flounder. The crustaceans and mollusks are generally considered separately, although the latter could be classified as either pelagic or demersal. Some 25 per cent of all fish caught belong to the herring family, while cod constitute about 16 per cent of the catch followed by mackerel with 6 per cent.

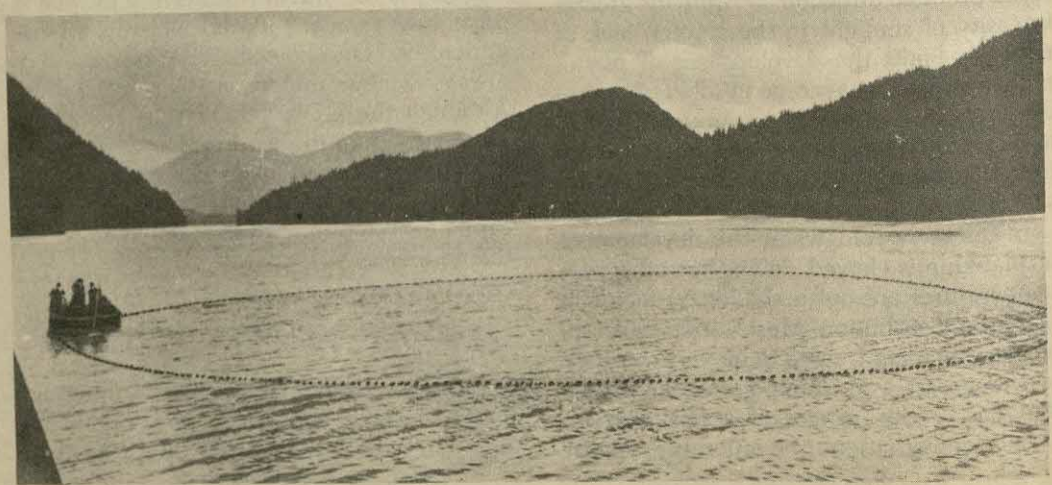
Significantly, 85 per cent of all fish are caught in the middle latitudes, for it is here that the greatest concentrations of one species occur and here that the market demand is greatest. In the tropics no one species dominates: catches are usually small, varied, and for local consumption.

Methods of catching fish. Technological developments in the fishing industry have been slow, due perhaps to the isolation of many fishing communities, the small size of many fishing fleets, and the consequent lack of capital available for improvement. There is an uncertainty associated with the fishing industry, and this does not encourage investment from outside. Furthermore, knowledge of the movements and life history of many kinds of fish is still relatively slight and the location of schools of fish often a matter of chance. Today, the means of catching fish range from the use of spears and small traps in the Pacific Islands and the Arctic to that of large, well-equipped fishing vessels that carry radar for detecting the presence of schools (Fig. 196).

The particular commercial method of catch used depends on the habits and the habitat of the fish sought. Pelagic fish, living near the surface of the water, are caught largely by drift nets and seines. Drift nets, which can be of many different lengths, are attached to slow-moving ships or floating buoys and kept vertical by means of weights placed along the bottom edge. The mesh is of such size that the fish is able to push its

Fig. 196. Catching fish with a purse seine off the Alaskan coast.

Courtesy U.S. Bureau of Fisheries



head through, but not its body; the gill covers are caught, and the fish can neither pull its head back nor pull its body through the net. Herring, mackerel and pilchards are among the fish caught by this method. Seines are of many varieties and designs, but most of them consist of a large net which is used to surround a school of fish. Gradually the ends of the net are drawn closer together, until a large number of fish are caught, and they may be removed either by hand or by lifting the net and its catch out of the water. This method may be carried out either by fishermen standing in the water near the shore, or from small boats.

Demersal fish live usually at depths of 200 feet or more, and they were formerly caught by *liners*, long ropes to which small lengths of cord and baited hooks are attached at regular intervals. Where the sea bottom is irregular, this system is still used, but the modern trawl, a large net of flattened conical shape, in some cases as much as a hundred feet long, is now more commonly used for demersal fishing. This huge bag is dragged slowly along the sea bottom by powered vessels. The trawl is most successful where the sea bottom is smooth.

Marketing problems. One of the fundamental difficulties the fishing industry has to face is the need to move the catch as quickly as possible to the market before it spoils. In the past this difficulty has been offset by using various methods of preservation, such as smoking and drying. Today, freezing and canning allow the fish to reach the consumer in a comparatively unaltered state. On the other hand, fishermen have to voyage greater and greater distances in search of large catches for expanding markets, so that the problem of keeping fish in good condition for longer periods of time creates a continual demand for more efficient operation.

Important developments in the fishing industry include the building of long-range fishing vessels that have freezing plants on board capable of storing large quantities of fish while voyages of several weeks are made. Also, "mother ships," which carry processing and freezing equipment and to which the fish are brought by "catchers," are being used increasingly. Some countries, particularly Russia and Japan, have built floating canneries to process fish far from the markets. More efficient mechanical handling gear and the use of marine radar, echo sounding, and other electronic devices for locating fish have helped the industry. Most of these developments have taken place in the countries where there are large-scale commercial fisheries and where the output per fisherman reaches 50 tons per year. In countries where simpler methods persist, output per fisherman may be only a few tons per year.

Fishing ports. The type of coastline, the nature of the land behind the coast, the transportation system in the area, and the size of the market all contribute to the importance of a fishing port in a region. The absence of sheltered deep-water harbors and the possibility of sea ice developing in the winter months tend to limit the growth of a fishing community. Formerly, fishing communities were small and served mostly local needs, but improved communications brought much larger regions within reach, and the ports with an efficient transportation system attracted more and more of the catch of a particular fishing area. Today, most countries with a commercial fishing industry have a few large ports with quick access to the more densely populated areas, while many smaller ports have declined in importance. For example, in Britain 4 out of some 130 fishing ports handle over 70 per cent of the catch, and many of the smaller ports now concentrate on developing their tourist industry. There are similar trends in most of the countries of Western Europe and in the New England states of the United States (Figs. 199, 201).

Larger catches and expanding markets necessitate better handling facilities at the ports. Characteristic of most modern fishing ports are good transportation facilities to nearby urban areas; plants for freezing, filleting, and curing; and, increasingly, plants for processing fish and fish wastes for meal, fertilizers, and oils.

Problems of conservation. Most fish are taken from the sea without any thought of replacement, and in areas of heavy fish-



Fig. 197. Sardine port of Safi on the coast of Morocco. The fishing vessels or "sardiniers," are now all powered by diesel engines. There are about seventy sardine canneries in Safi.

Courtesy of "The Lamp," Standard Oil Company of New Jersey

ing the catches have been decreasing since the beginning of the century, despite, or perhaps because of, improved catching methods. During the First and Second World Wars, however, fishing activities in some areas lessened, and in the years immediately following catches increased significantly, only to decline again after a few years of heavy fishing. This indicated that fish stocks were being depleted more quickly than they could be replenished by natural means, and the problem of overfishing has been drawing increased attention since the 1920's.

Plans to maintain fish stocks at the maximum sustainable yield—that is, to fish as intensively as possible and obtain the same quantity and quality of fish year after year—are hampered by a number of difficulties. Knowledge of the life history of many species of fish is still in its infancy. Some, such as the cod, thrive best within very limited water-temperature ranges and seldom thrive where the sea bottom is muddy. Others move in, as yet, little understood migration patterns: the herring, for example, appears off northwestern Britain in early spring and by late summer is found in the English Channel. At the beginning of the century herring catches were made in the Channel, but at present the supply has declined to such an extent that it is no longer worthwhile for boats to move out of the North Sea. Whether the decline of the herring in the Channel is due to overfishing for industrial use or to the migration of the species to another part of the ocean, is not known. Another difficulty is that precise estimates of fish populations are not easily made in any one area. In addition to this lack of basic knowledge there are many administrative problems associated with plans to conserve fish resources. Any international conservation agreement requires the participation of all the countries fishing in the waters concerned, and while such participation is difficult to obtain, the enforcement of an agreement is even more difficult. During the 1930's most of the countries fishing in the North Atlantic agreed to limit the

mesh size of their nets so that only the larger fish were caught. Inspections are held to insure that immature fish are not taken, but, because different fish sizes make it necessary to compromise as to the mesh size of the nets, it is not possible to avoid catching the young fish of some species. Other conservation measures suggested for the future include keeping fishermen out of areas where spawning is taking place or where there are large numbers of young fish. Over-all catch limits might also be prescribed for some species, and closed seasons delimited. The type of gear used can also be controlled, and it has been suggested that fish should be propagated and the young transferred to areas where there is a good supply of plankton. This latter measure has already achieved some success on a small scale.

Anyone can fish on the high seas, but there is continuing disagreement as to how far from its shoreline a country has sole fishing rights. For example, Iceland, whose economy depends on fish, has claimed a 12-mile limit around her territory. Others claim 3 to 6 miles, and at present most questions of this type are settled by means of bilateral agreements between individual countries. Eventually, however, some international agreement will have to be made.

THE MAJOR FISHING AREAS

As with the utilization of any resource, the world pattern of fisheries is governed by the location and quality of the supply, the demand, and the technique available to use the resource. If there are large quantities of fish in an area, particularly large numbers of a few species, commercial fishing is possible, providing there is a demand from nearby countries and modern techniques are available. In the middle latitudes of the Northern and Southern Hemispheres such conditions exist, but it is only in the Northern Hemisphere that fishing industries have developed on any large scale. Off the coasts of North America, eastern Asia, and western Europe the sea is fished intensively, but off South America, where there is a considerable potential, the industry is, as yet, underdeveloped because there is only a relatively small demand.

In some countries there is a shortage of other proteins, and the population exploits the resources, whatever their quality, and with whatever techniques are available. Around some tropical seas as in the Australasian archipelago, in parts of the Caribbean area, and in Melanesia and Polynesia, fish is an important supplement in the diet of the people, but, because techniques are often simple and because the nature and variety of tropical species of fish do not allow them to be caught in commercial quantities, commercial fishing in these areas remains a comparatively small-scale enterprise.

The four leading fishing areas of the world are: (1) the northwest Pacific, that is, the seas bordering northeastern USSR, northern and central Japan, northern China, and Korea; (2) the northwest Atlantic, the great fishing banks of the Atlantic off the coast of Newfoundland and New England and the shallow coastal waters to the south along the eastern and southern coast of the United States; (3) the northeast Atlantic, the extensive shallow waters off the European coast, from the Barents Sea in the north to the Bay of Biscay and farther southward to the coastal waters of the Iberian Peninsula and Morocco and Río de Oro in Africa; and (4) the northeast Pacific, the Pacific coast of North America from Alaska to California (Fig. 198).

Each of these areas supports large fishing fleets and has fishing industries employing thousands of people. From each the catch serves as an important food supply and provides a commodity of great commercial value. It is well to note, however, that fishing plays only a minor role in the economy of even the most important commercial fishing countries. For example, Norway, with the fourth largest catch in the world, has out of a population of 3,500,000 people only 70,000 fishermen, and only a third of these are full-time fishermen. Fish provides only 4 per cent of Norway's national income, although it accounts for 20 per cent of the exports.

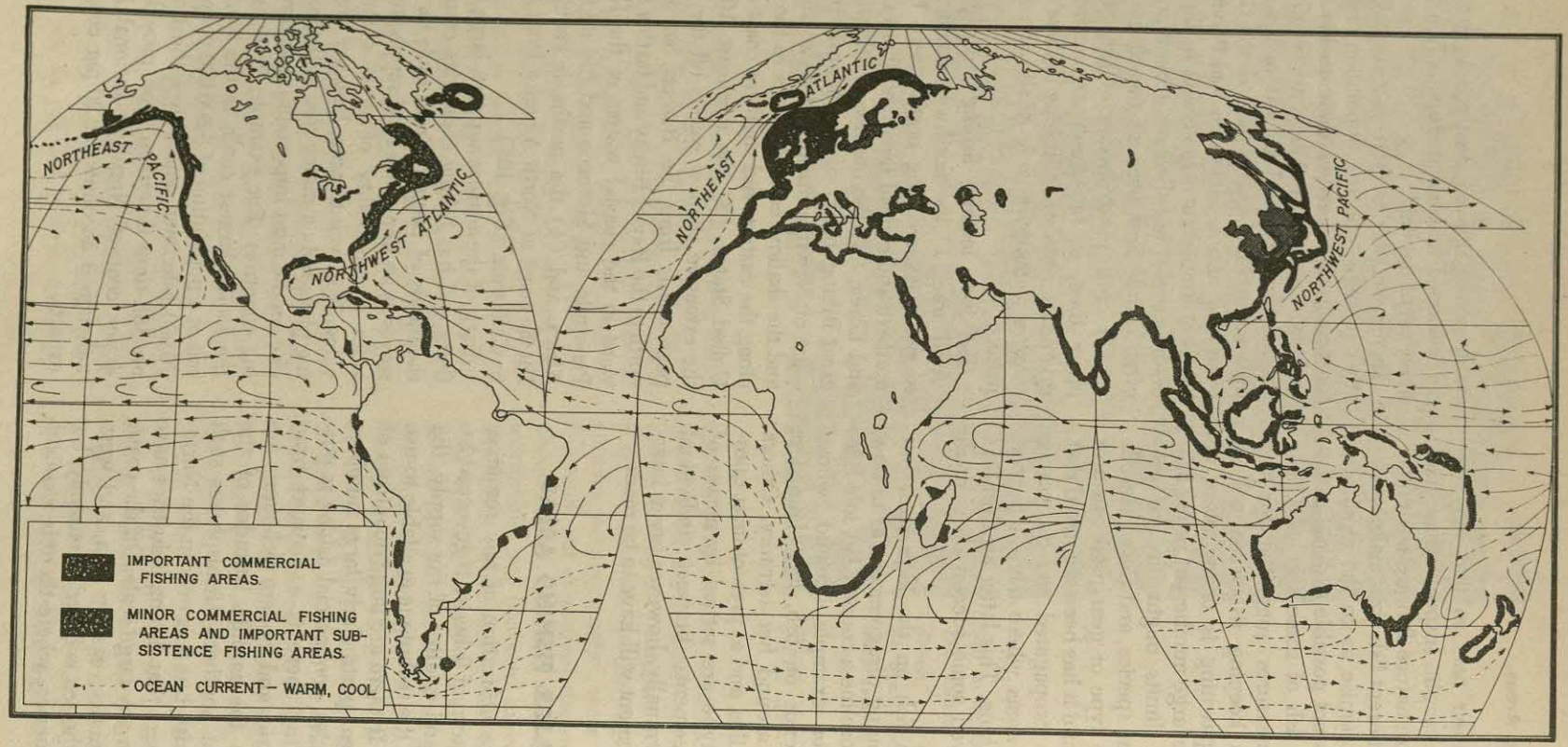
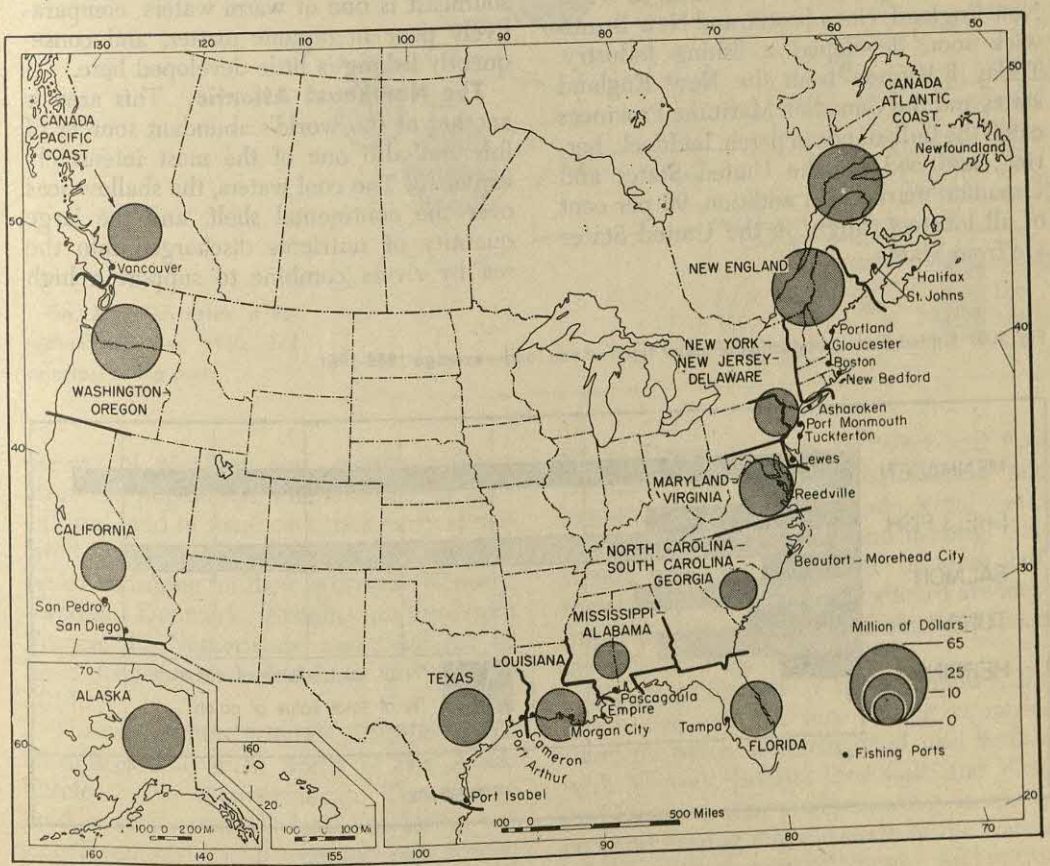


Fig. 198. Principal fishing areas of the world.

The Northwest Pacific. In this region the greatest catches are made. From the Aleutians to southeastern Asia the seas are fished in varying degrees of intensity by all the bordering countries. A wide continental shelf and the meeting of the warm Kuroshio or Japan current from the south and the cold Oyashio or Okhotsk current from the north are the underlying causes for a dense fish population. The cold waters off the northeastern coast of Russia provide her with a quarter of her annual catch. In terms of value and weight, salmon leads the output from the area, and, because of the great distance from the Soviet Union's domestic markets, much of the catch is canned both on shore and afloat. Other cold-water varieties of fish are caught, but so far only the herring has been caught in any quantity, though cod is slowly increasing in importance. This is an area of great potential.

Southward the seas become warmer, and tuna, mackerel, sardines, and allied varieties are taken from the sea in large numbers by Japanese and Chinese fishermen. The seas around Japan and China are the most intensively fished in the world, and, in addition to the pelagic and demersal species in Japanese and adjacent waters, a very large tonnage of shellfish is caught. Most of the Japanese catch is eaten fresh or cured, but increasing amounts, particularly of tuna, sardines, and oysters, are being canned for export. Although detailed information on China is lacking, intensive fishing takes place in coastal and adjacent waters, which yield a catch estimated to equal Japan's. Most of it is consumed immediately, and there does not appear to be much commercial exploitation or significant industrial

Fig. 199. Catch of sea fish, Anglo-America, 1960-62, by major fishing districts. Also shown are principal fishing ports.



utilization. In general, the fish are caught from small boats a few miles off shore, and, as yet, there seems to be little development of long-range trawling. Fish raised in ponds and caught in lakes and rivers also contribute to Chinese production.

The Northwest Atlantic. From Cape Cod eastward and northeastward the continental shelf widens, and thousands of square miles of shallow seas rich in plankton form the basis of an intensive fishing industry. Vertical movements of water caused by the meeting of warm Gulf Stream water and cold water from the Arctic—the Labrador current—brings organic material to the surface. The zones of shallowest water are known as *banks*, of which the Grand Banks, southeast of Newfoundland, is the largest, and they are fished both by European and North American fishermen (Figs. 198, 199).

In early colonial times offshore fishing supplemented the relatively poor yields from the agricultural lands near the shore, and the inhabitants of the coastal areas of New England, Nova Scotia, and New Brunswick soon developed a fishing industry. Today fishermen from the New England states and the Canadian Maritime Provinces catch the bulk of ocean perch, haddock, herring, and cod for the United States and Canadian markets. In addition, 90 per cent of all lobsters caught in the United States are from Maine.

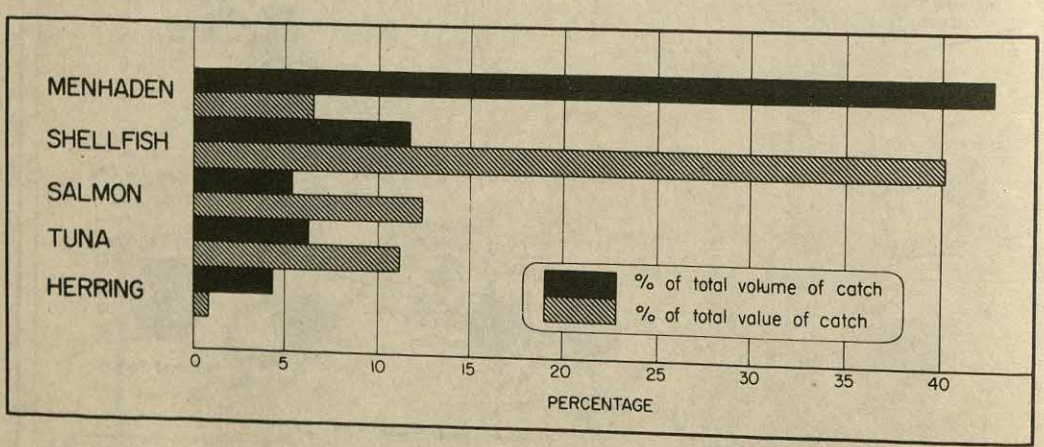
Farther south, off the Middle Atlantic states, the seas become warmer, and menhaden, a pelagic fish, dominates the catch. It leads, by volume, all other species of fish caught in the United States and is of great industrial importance, being processed into meal for the manufacture of fertilizers, animal feeds, and oil for paints and soap. Along the coast of the Middle Atlantic states, and particularly in the Chesapeake Bay area, the largest shellfish fishery in the world is concentrated. Crabs, oysters, scallops, and clams combine to give a catch of high value, most of which is caught from the shore or on short voyages (Fig. 200).

The shelf widens again in the Gulf of Mexico, and here also increasingly large catches of menhaden are being made. Shrimp fisheries, too, are of great significance, being the largest in the world and shrimp being the most valuable single species caught in the United States.

The Caribbean area to the south and southeast is one of warm waters, comparatively poor in organic matter, and consequently fishing is little developed here.

The Northeast Atlantic. This area is another of the world's abundant sources of fish and also one of the most intensively exploited. The cool waters, the shallow seas over the continental shelf, and the large quantity of nutrients discharged into the sea by rivers combine to support a high

Fig. 200. United States production of major types of sea food—average 1958-1961.



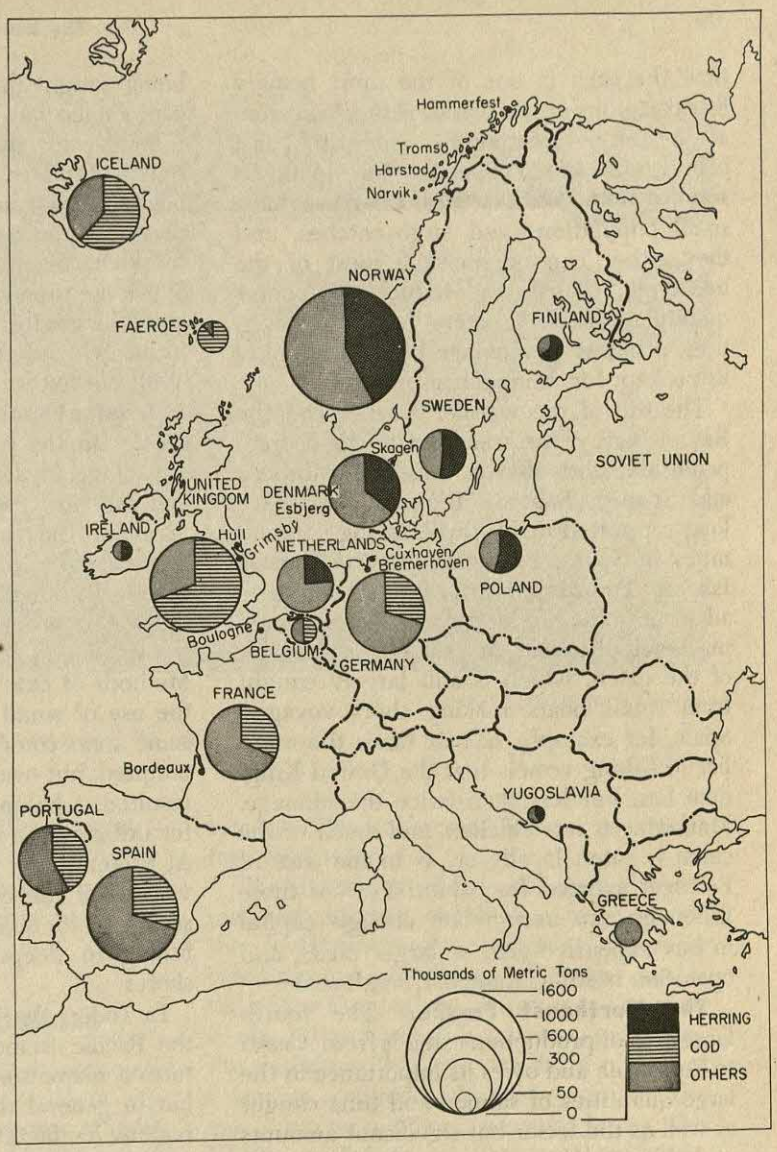


Fig. 201. Fish catch of European countries, 1960, and principal fishing ports.

density of plankton and, consequently, a large fish population. The shortage of agricultural land in some countries early stimulated the growth of communities which relied on fishing for their existence. Norway, Sweden, Denmark, Britain, northwestern France, the Netherlands, and Portugal, all have long-established fishing fleets (Fig. 201).

The main fishing grounds of northwestern Europe extend from north of the Arctic Circle to the Mediterranean. The remote cold waters around Iceland are fished, not only by countries with relatively easy access, such as Iceland itself, Norway, and the Soviet Union, but also by West and East Germany, the Netherlands, France, and Britain, whose trawlers spend several weeks at a time fishing for cod and herring. Efficiently operated, long-range trawlers with their own freezing facilities aboard are most important where distance from the market necessitates long preservation.

The most intensively fished region is the North Sea. All the surrounding countries share the catch of herring, cod, and flatfish, with Norway, Britain, Denmark, and West and East Germany predominating. In spring cod and herring migrate south to the waters off the northern coast of Norway, and at this

time the area is one of the most heavily fished regions of the world. Fishermen from all the fishing communities along the coast converge to catch some of this immense supply. Both Norway and Denmark have small populations and large catches, and they either can or preserve most of the better-quality fish and reduce the poorer quality to meal. In more populous countries, a higher percentage of better-quality fish is kept for human consumption.

The fish of the warmer Atlantic—off the Bay of Biscay, the area west of the Iberian peninsula, and off the coasts of Morocco and Spanish Sahara (Río de Oro)—have long supported many small fishing communities in Spain, Portugal, and the Canary Islands. The same is true for the countries adjacent to the Mediterranean Sea. Sardines, mackerel, pilchards, and tuna form the bulk of the catch, which is still largely caught from small boats making short voyages. Spain, for example, has six times the number of fishing vessels that the United Kingdom has, but less than twice the tonnage. Marketing is less efficient, and much of the catch is eaten locally or, as in the case of Portugal, canned for export. Few of these fishermen can accumulate enough capital to buy expensive gear or larger boats, and operation is still, essentially, small scale.

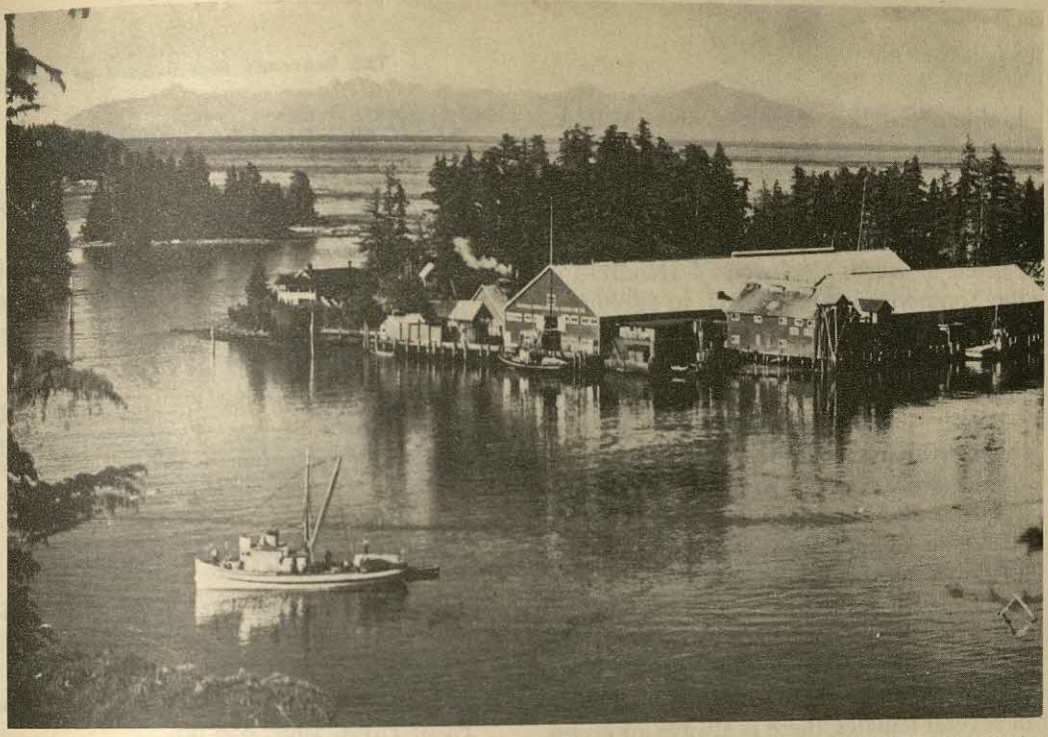
The Northeast Pacific. The fourth large area of production extends from Alaska to California and owes its importance to the large quantities of salmon and tuna caught as well as the lesser but significant amounts of halibut and sardine. In the north the salmon dominates the catch, both in value and quantity. The fish are caught as they enter the rivers for spawning, the areas near the mouths of the Columbia and Fraser rivers and Bristol Bay in Alaska being the most outstanding. Canneries have been built along the coast for, although about one quarter of the catch is marketed fresh, salmon does not preserve well and should be utilized as soon as possible. The Alaskan area is becoming relatively more important because to the south overfishing as well as some lumbering activities and electrical and irrigation projects have tended to diminish salmon supplies. Halibut and herring are being caught in increasing amounts in the cool Pacific waters (Figs. 199, 202).

Southward the California current, composed of water which has upwelled from below, is rich in nutrients. Salmon catches decrease, and tuna takes the lead, followed by pilchards and mackerel. For the United States the tuna catch is the third most valuable, the greater part being canned in California, which has the largest cannery output of all the states.

Tropical seas. The immense variety of species in the tropical seas is a great disadvantage in the development of commercial fisheries. Plankton content is low, and many of the fish are less palatable than those caught in cooler waters. At present, practically all the countries concerned use the waters around their coasts, but catches are small and for immediate consumption. Methods of catch are simple, ranging from the use of small nets to that of spears. In some areas commercial fishing has been attempted, but overfishing and depletion have resulted. A balance must therefore be found for utilizing the limited resources available. At present, only the areas in the immediate vicinity of the coasts are fished, but there seems to be some potential for industrial fishing in deeper waters away from the shores.

In India, the southeast Asian countries, the Pacific islands, and Africa fish constitutes a major source of protein in the diet, but in general this is true only for coastal regions, as facilities for preserving fish are very few.

Areas of considerable potential. The main areas of potential development in the world lie in the Southern Hemisphere and adjacent countries with low population densities. Off the southwest coast of Africa upwelling of cold water occurs and forms the Benguela current; this area has dense concentrations of fish caught in increasing quantities by South African fishermen. Similarly, cool waters off the coasts of Chile and Peru and those of the continental shelf area of Argentina are continually replenished with nutrients and also support a dense population of pelagic fish. The waters of the Peruvian current are being increas-



Courtesy U.S. Bureau of Fisheries

Fig. 202. One of the numerous salmon canneries on the coast of Alaska.

ingly used, but, as yet, these South American waters are not exploited to the fullest extent. With improved methods of preservation and transportation, they will undoubtedly receive more attention.

OTHER MARINE RESOURCES

The whaling industry. Sea mammals are not strictly fish, but they make a significant contribution to the economy of most large fishing nations. Whales, in terms of both weight and value, lead in importance, with seals some distance behind.

The southern oceans, south of latitude 50°, provide almost two thirds of the whales caught each year, the other third coming mainly from the North Pacific and North Atlantic. The waters where they occur are zones of upwelling where nutrients are brought to the surface and support a high density of plankton, particularly the variety known as krill, on which most of the whales caught rely for their existence. Oil, obtained by boiling the thick coat of blubber, is by far the most important product and is used in the manufacture of soaps, foods, and lubricants. The bones and meat are processed into feedstuffs.

The remoteness of the cold waters where most whales are caught has necessitated the development of an efficient system of catching and processing. When the potential of the far-southern waters was first realized a little over half a century ago, it was the nations with a long tradition of fishing that first equipped whaling vessels for the sub-antarctic waters. Norway, Japan, the USSR, and Britain, all Northern Hemisphere countries, take three quarters of the catch, while the Republic of South Africa, South America, and Australia, despite their proximity, account for no more than 10 per cent. The great distance from markets has led to the establishment of bases on islands of the South Atlantic, notably on South Georgia, the South Shetlands, and the Falkland Islands, from which the *factory ships* and their catchers operate. An antarctic whaling expedition today consists of a factory vessel accompanied by several high-powered catcher boats equipped with harpoon guns. Much of the processing is done aboard the factory ships, which have boilers for the

blubber, grinding machines, storage tanks, and all that is necessary to handle up to a dozen whales a day.

Increased efficiency of catching methods has resulted in larger catches, but this has caused a serious depletion of resources in the Southern Ocean. In 1947 an agreement was signed to limit the number of whales caught each year. Unfortunately, it is difficult to know whether all keep within the set limit. There is, as yet, no such limit in the Northern Hemisphere, and catches of whales are increasing steadily.

Fur seals. Seals are a resource of some economic significance, the Pribilof Islands off the coast of Alaska being the chief center of the fur-seal industry. Each year thousands of seals come to these islands for breeding, and since they live in a harem system, whereby each male has possession of several females, there is always an excess of male seals. United States government officials select animals from this surplus for killing, and this supports a flourishing industry without depleting resources. Formerly seal populations were much larger, but excessive exploitation in the nineteenth century by the Americans, British, and Japanese reduced the numbers so much that they ceased to be of commercial importance. It was only by the constant effort of the United States government that conservation was possible and that the seal herds began to increase. Pelagic sealing is now forbidden by international agreement. The United States obtains 80 per cent of the skins from the Pribilof Islands, Russia and the European countries sharing the rest.

Other resources. The sea contains every known mineral in solution or deposited on its floor. Sodium chloride has been obtained for hundreds of years by evaporating sea water. In recent years economic means of extracting other minerals have been found. Bromine and magnesium are now produced in economic quantities, but, as yet, most other minerals can be obtained more cheaply from the land. Coal and oil exist in the sedimentary rocks underlying parts of the ocean and are exploited to some extent near the shore, particularly oil.

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19

Introduction to the Mineral Resources

peculiar characteristics of mineral exploitation

In former times the basis of economic life everywhere was the land—be it pastureland or tilled land—but now, in all those parts of the world that have a power-machine type economy, it is the mine. Without coal, oil, and other forms of mined power, modern machinery could not run; without iron, aluminum, copper, and a host of other metals and mined substances there could be no machines of the many types we use today. In order to understand modern production one should have an understanding of mineral resources, of the nature of minerals, their chief uses, and their various modes of occurrence. In order to understand modern economies one should have an appreciation of the geographic distribution of the major minerals and understand some of the factors that enter into mineral exploitation, some of the circumstances peculiar to such exploitation, and some of the socioeconomic implications and consequences of mineral exploitation.

LAND CONTENT

Land content has been defined in Chapter 1 and has been studied in regard to soils and agricultural productivity and in connection with the various discussions of climate and agricultural regions.

Below the soil, and usually not far below it, lie various rocks, among which there may occur concentrations of minerals that are important for development of power or for the manufacture of the thousands of items produced by our modern economy.

In Chapter 4 the term *mineral* was defined, and a few examples of minerals were given. The examples were all of minerals that are important in the formation of rocks. Several of these also play a modest economic role.

However, none of the numerous minerals that are major sources of metals were mentioned at that time.

MINERAL RESOURCES

When we speak of mineral resources, the word "mineral" is taken in a somewhat broader sense than allowed by the more

scientific definition referred to above. True, many of the mineral resources consist of concentrations of such metal-containing minerals as hematite, chalcopyrite, galena, sphalerite, cassiterite, and many others, but in mineral production it is customary to include also such items as stone for building purposes or for use in broken form, clay, sand, gravel, and lime as derived from limestone. In other words, certain sedimentary, igneous, and metamorphic rocks are included. In addition, coal, usually looked upon as a mineral, is by strict definition really a sedimentary rock. Also water as a consumption good, but particularly as a source of power, is always included (Fig. 203).

Major groups of minerals. As stated in Chapter 4, the total number of known minerals is large, but a great many of them are scarce and of interest primarily to the mineralogist and the mineral collector. The number of major rock-forming minerals is, as has been seen, quite small. That of minerals which contain metals and other substances of interest to man is considerably greater, but the number of those that occur in sufficiently large quantities to be of economic interest is again quite limited.

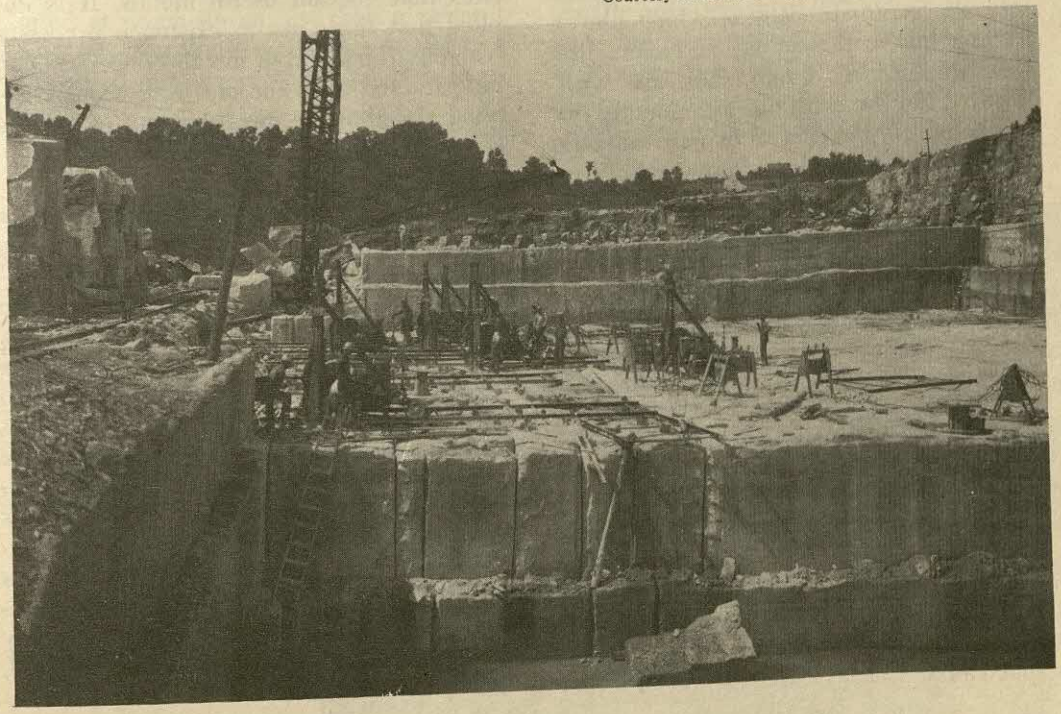
From a "use" point of view the minerals of economic importance may be put into four groups:

(1) the power minerals
(2) the precious minerals
(3) the industrial metallic minerals
(4) the minerals of direct economic use

The power minerals are those which are used chiefly, though not entirely, for conversion into energy, for example, peat, coal, and oil. The precious minerals are those that have high value because of comparative scarcity but that still can be put into usuable form, either for purposes of decoration or exchange. To this group belong gold,

Fig. 203. Quarrying, a common form of mining. The term is generally applied to open-pit mining of rock, not of coal or other minerals. Quarry in Indiana limestone, a major building limestone in the United States near Bloomington, Indiana. This oolitic limestone is unusually massive.

Courtesy Indiana Limestone Company, Bedford, Indiana



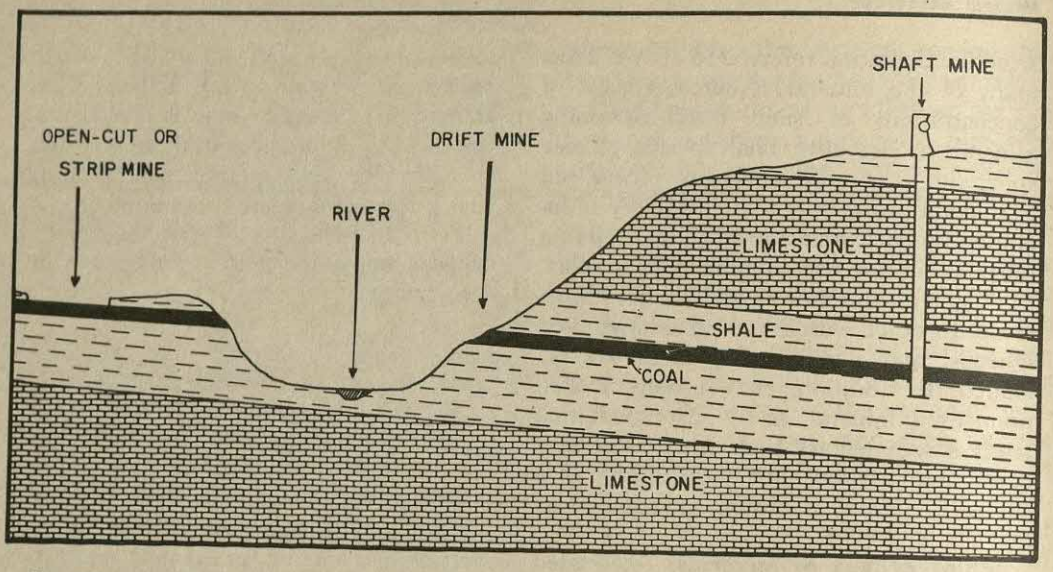


Fig. 204. A simplified diagram showing three methods of coal exploitation. Of course, in reality the three methods are not likely to occur in such proximity.

silver, platinum, diamonds, and other gem stones. Several of these also have some industrial usefulness, although this is a subordinate aspect. It is not possible within the scope of this book to further discuss this group.

The industrial metallic minerals constitute a large group, many of which play a leading role in present-day economic life. Like the previous group, they are withdrawn from the earth not as minerals but as mixtures of the mineral or minerals concerned and rock matter—mixtures which are commonly referred to as *ores*. For example, pure magnetite contains 72.4 per cent metallic iron, but magnetite ore is of very high grade if it contains as much as 60 per cent iron, due to such admixtures.

The extraction of the mineral from the ore is usually a fairly difficult and complex procedure which requires a great deal of technical understanding and knowledge as well as heavy investment in in-plant transportation equipment, buildings, large and complicated machinery, and many other items.

Finally, the last group is made up of minerals and rocks that are more or less directly suitable for industrial purposes or that can be made so by means of fairly simple processes: limestone, which only requires grinding and some simple manufacture to be made into lime or cement; stone for crushing; clay, salt, asbestos, and others.

Ores. As stated above, an ore is a mixture of rock matter and one or more minerals that contain useful metals. It is implied that there are in existence processes whereby the metal or metals concerned can be extracted from the ore. It is usually implied also that the metal content of the ore is sufficiently high to make it economically attractive to do so.

However, the appropriate metal content varies greatly from metal to metal—it varies in time with changes in technique and economic circumstances, and it varies in place according to geographical circumstances.

Iron ores as exploited at the present time generally carry an iron content of from 30 to 60 per cent iron, but copper ores, if available in sufficiently large quantities, may be of economic interest even if the copper content is less than one per cent. Improvements in technique often make it possible to utilize lower-grade ores or material that has been rejected previously. Flotation processes, for example, made possible recovery of copper from old, worked-over material, so-called 'tailings.'

Changes in economic circumstances may make it feasible to use ores that ordinarily are of too low a grade. During World War II, when imports of high-grade ores or of the metals concerned were suspended, many countries were forced to start mining ores which in normal times would not have been good enough. Boom and depression periods may have similar effects: during periods of high demand even marginal mines may be able to operate at a profit, while during depression periods even some of the better mines may have to close down. The appropriate metal content also varies with geographical circumstances. It is clear that a mine located far from major market areas or in an unfavorable environment can be exploited only if its ore is of comparatively high grade.

Modes of occurrence of mineral resources. The modes of occurrence vary greatly and are of prime importance from an economic point of view because the various physical circumstances which surround the occurrence greatly influence modes and costs of exploitation. To take but one example, a mineral that occurs so near the surface that modern steam shovels can remove the overlying material can be exploited at much lower cost than a mineral which lies at a depth of 2,000 feet and can be reached only by construction of a deep shaft.

Mineral resources, such as limestone (of a quality suitable for cement or other manufacture) and coal occur in strata, and exploitation can follow these strata; thick strata are, of course, of greater economic interest than thin ones. If near the surface, the limestone beds or coal beds (or coal *seams*) can be exploited in open cuts. If the coal beds occur at greater depth, they can be reached by sinking shafts, or if coal seams crop out on valley sides, by means of horizontal or near-horizontal *drifts*. The strata are usually fairly continuous, unless interrupted by faults (Figs. 204, 205).

Metallic minerals often occur highly scattered through rocks. In fact, they may be so highly dispersed that it is not economically feasible to recover the mineral. Exploitation usually pays only if, as a result of various natural circumstances which cannot be discussed here, there have developed underground some areas where the mineral has become concentrated to a greater or lesser extent. These are the so-called *ore bodies*. Some minerals, iron minerals for example, may occur as stratumlike bodies. Others occur as *veins*, such as fillings of rock cracks, be they large cracks, such as joints, or very small cracks. There are still other types of veins, but all vein deposits are usually quite irregular. Important veins may be found in an underground area, but there is no assurance that they may not suddenly disappear beyond that area, perhaps to reappear again some distance farther on. Ore

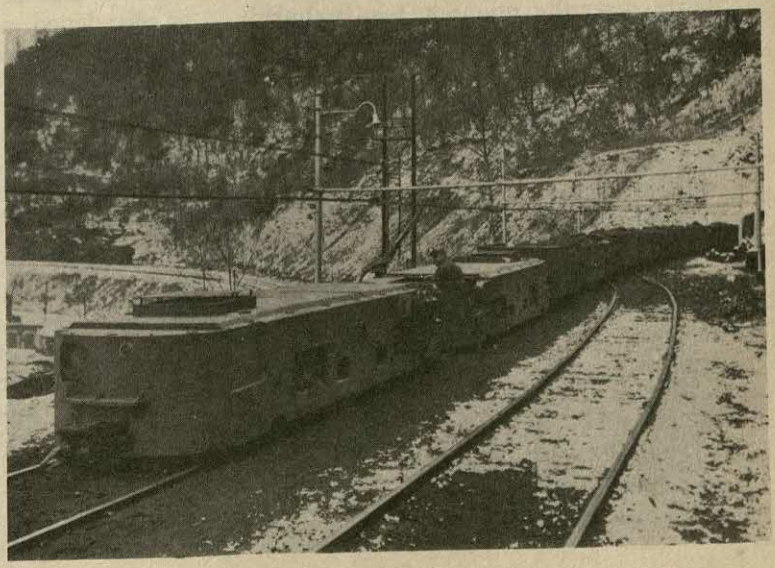


Fig. 205. Large scale underground mining. Loaded coal cars leaving a drift mine in the Appalachian coal field. Entrance to the mine is just visible to the right. Note the two powerful locomotives specially built for underground haulage.

Courtesy National Coal Association, Washington, D.C.

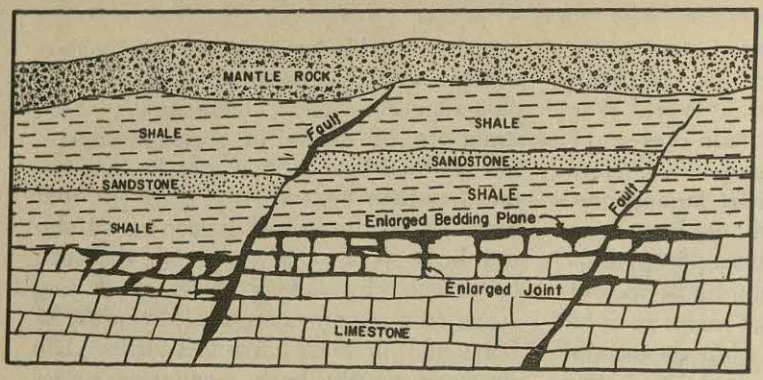


Fig. 206. A simplified presentation of how minerals may be deposited in fault, bedding, and joint cracks.

bodies, therefore, are often of extremely irregular shape, not only in two but in three dimensions. It is also difficult to forecast how much ore there may be some distance away from the area of exploitation. Even when considerable drilling has been done in adjacent areas, it is often difficult and hazardous to come up with definite figures on "available reserves." (See Fig. 206.)

Geographic distribution of mineral resources. An outstanding characteristic of mineral resources is their highly irregular distribution over the world. There are areas that are very rich in a variety of mineral resources, such as the southern and central Ural Mountains of Russia, others that are apparently comparatively poor, such as the Amazon basin proper of South America and the coastal plain of the United States from Georgia to Maryland. Also, minerals differ in the irregularity of their distribution; for example, salt is distributed fairly generally and not too irregularly, while tin and vanadium occur only in a few and widely separated places.

One consequence of this irregular distribution is that some countries are fairly well off insofar as minerals are concerned, such as the Soviet Union and the United States, whereas countries such as the Netherlands, Finland, Japan, the Central American republics, and many others have comparatively little. Another consequence is that trade in minerals and mineral products is quite important, particularly since our modern economy calls for such a wide variety of minerals that even the best endowed countries are not self-sufficient. In this respect the United States is so far from being self-sufficient that in these uncertain times it has been deemed advisable to accumulate stockpiles of mineral items in which the country is in short supply. The irregular distribution of minerals has also led to many political repercussions.

Mineral exploitation. A chief characteristic of mineral exploitation is its spotwise occurrence, in contradistinction to agricultural exploitation, which is usually areal. Mining districts are often small, and frequently they are not near any of the larger cities and are difficult to find even on detailed atlas maps. In the more extensive mining areas, such as in coal fields, the locations of the actual mines frequently are well scattered. Nevertheless, mines are often very distinct items in the landscape, as mining is apt to disturb the natural landscape far more than agricultural exploitation does. The occurrence of huge piles of rejected material, that of extensive open cuts, active or abandoned, and the large-scale cutting of timber for mine use frequently causes disfigurement of the landscape (Figs. 207, 208).

Another aspect of mineral exploitation is that usually the best and most easily available supplies of a mineral are mined first, making it necessary to proceed later to the mining of poorer ores, occurring at greater depth. In other words, mining is an "increasing-cost" economic activity. Of course, increasing-cost items can be neutralized by improved techniques of mining and of recovery of the metal, but these have definite limits beyond which rise in cost becomes inevitable. There are many mining regions which have ceased functioning, and the

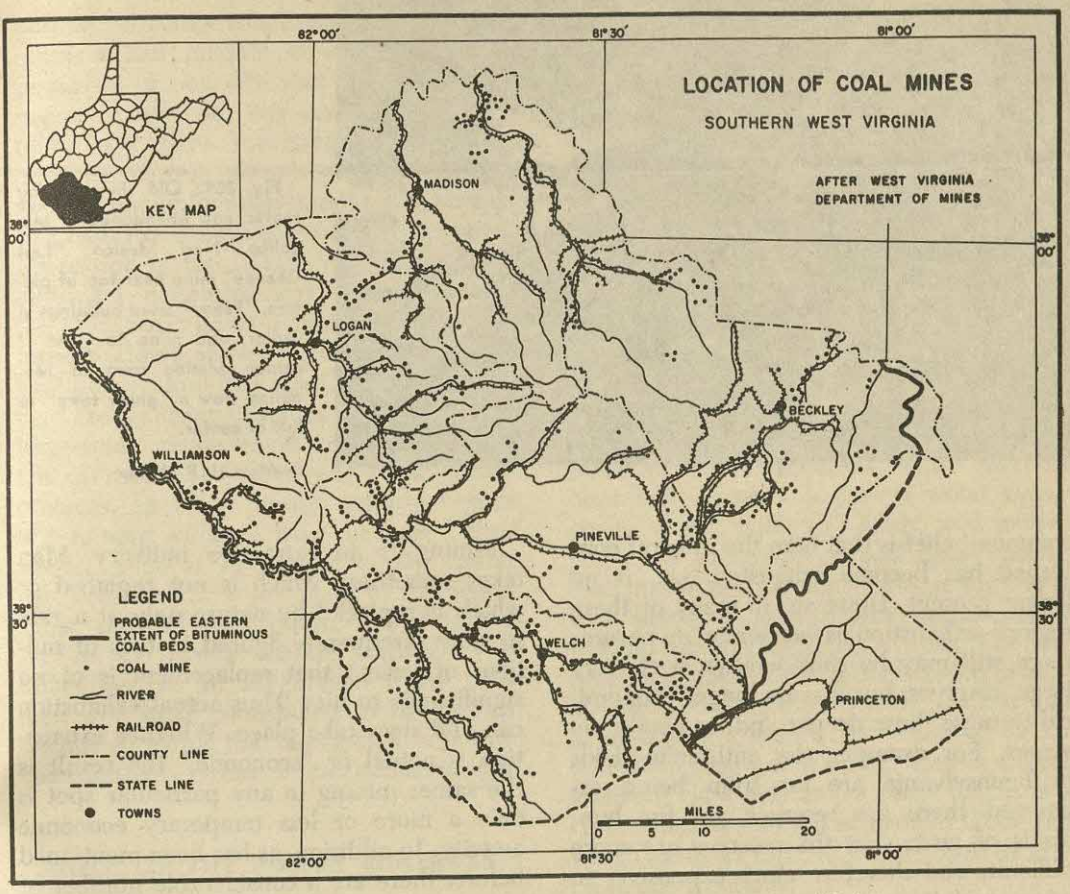


Fig. 207. An example of the dispersed location of mines—even in an area very rich in a certain mineral resource, in this case coal.

Fig. 208. Area of old underground coal mining south of the city of Mons, Belgium. The hills are entirely man-made: they are the accumulated refuse from mining.

Courtesy European Community Information Service

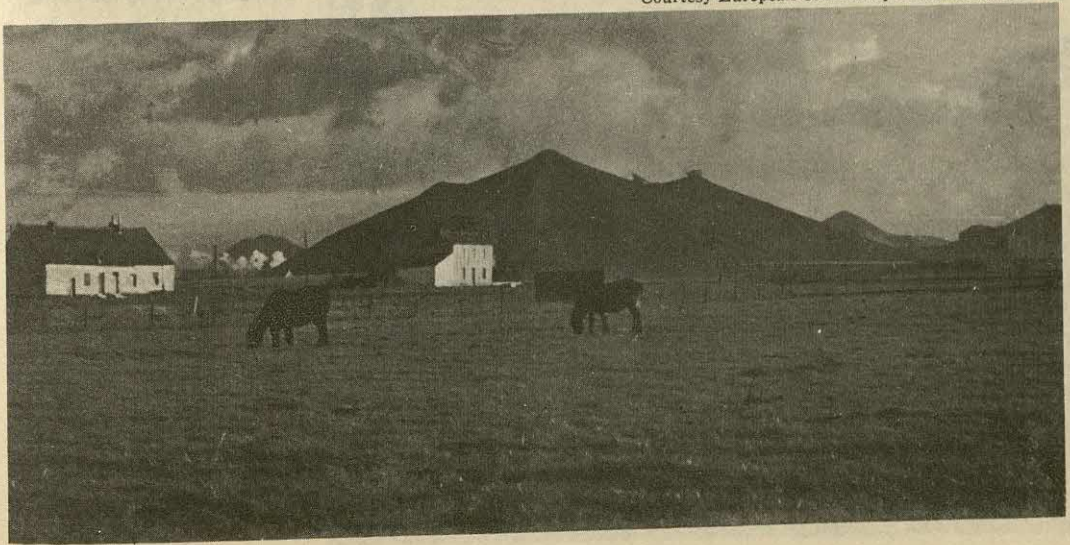




Fig. 209. Old silver mining center, now abandoned at Mogollon, New Mexico. "Last Chance" mine near top of picture, "Fanny" mine buildings in center, and mine to right of center. Mining town of Mogollon, now a "ghost town" to left of center.

Courtesy M. R. Walton

common belief is that here the mineral concerned has become exhausted, i.e., is no longer present. However, in many of these regions exhaustion is economic in nature: there still may be considerable, even very large, reserves, but it is no longer economical to mine these deeper and/or poorer reserves. For example, the anthracite fields in Pennsylvania are far from being exhausted—there are reserves yet for hundreds of years—but the reserves are more difficult, and therefore more expensive, to mine, and it is now easier and, in many places, cheaper to heat a home with gas or oil.

Mining is an extractive industry. Man takes something which is not replaced or which is replaced by nature only at a rate so slow (frequently figured in tens of millions of years) that replacement is of no significance to him. Thus actual exhaustion can and does take place. Whether exhaustion is actual or "economic," the result is the same: mining in any particular spot is only a more or less temporary economic activity. In addition, as has been mentioned before, there are a considerable number of marginal mining enterprises, and even those that are not economically marginal may be affected seriously by changing or deteri-

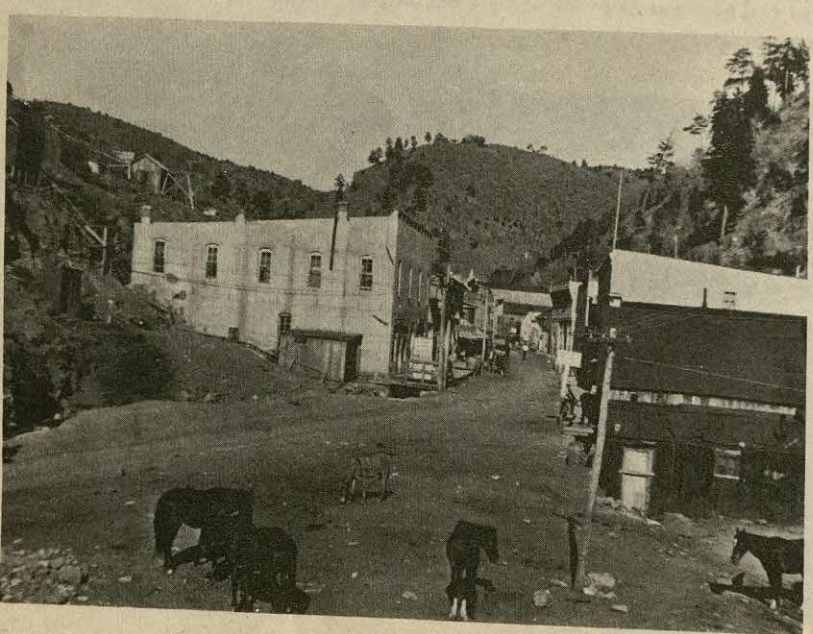


Fig. 210. View of the now abandoned mining town of Mogollon, New Mexico.

Courtesy M. R. Walton

orating economic conditions. As mining requires a fair amount of concentration of people at or near the spot where the mining is carried on, this comparative instability will have inevitable social consequences. During periods of low economic activity unemployment in mining areas may be great. For example, during the economic depression of the 1930's the effects of such increased unemployment were visible in the Lake Superior iron-mining region in the form of closed stores, neglected homes, vacant houses, and half-filled schools. In coalfield areas closing of mines and, in addition, large-scale replacement of men by machines may have disastrous social consequences. In many former mining regions the mining villages have become "ghost towns," such as in sections of the American West and in other parts of the world. Thus, mineral exploitation, though necessary for the general welfare, is fraught with difficulties. In an enlightened world those men who have contributed to the general welfare by doing the mining should not become helpless victims of inevitable changes.

ROLE OF THE POWER MINERALS

Among the minerals the group of power minerals is basic: machine production of goods is not possible without access to inanimate sources of energy, such as coal, oil, gas, water power, and, perhaps in the near future, nuclear energy plus some amounts of power derived from tides or obtained directly from the sun.

Earliest power resources. The evidence now available upholds the idea that in prehistoric times women were the ones who domesticated plants and first tilled the soil with sticks or branches, stones, and bones, crudely fashioned into the predecessors of the modern hoe, spade, and rake. It seems probable that for aid in work of this kind some animals more tractable than others were induced to pull boughs or branches over the newly "spaded" ground in order to prepare a better seedbed for the crops. In some such manner, long before the dawn of recorded history, animals were domesticated to serve directly as sources of power to supplement muscular energy. Nevertheless, the extent to which man could use animals for this purpose was slight, and he continued to depend in large measure upon his own muscular energy to carry on the production processes necessary for his existence.

Human slaves as power resources. The necessity of supplemental power to create high standards of living for some people served until quite recently as the basis for widespread systems of human slavery. In the wars of ancient and medieval times, the victors obtained slaves from the ranks of the vanquished to be used as household servants, hewers of wood, drawers of water, pullers of loads, and motive power for merchantmen and naval vessels. The production per slave was small, yet it was somewhat greater than was necessary to keep him alive and fit for work. The surplus production thus available aided in supplying the ruling classes with luxuries and in sustaining a leisure class essential for intellectual progress. This, of course, means a leisure class only in the sense that it is a class which is relieved of manual labor and which earns its right to live through its cultural contributions.

During most of the historic past the toiling majority of the people achieved but low production per capita and slight available surplus. As a result, they lived on a standard so low that today we would consider it to be submarginal, whereas the rich, with all their wealth and luxuries, in many cases did not have the comforts available to most of the common people in the progressive nations of the present. Part of this aristocratic class, however, was instrumental in sponsoring the progress of the arts and sciences. The steady advancement of mankind in science and in the fine arts has been due in no small measure to the constructive accomplishments of the useful part of this class. "The Golden Age of Pericles" is often referred to as representative of man's highest intellectual achievements. Midst praise of this type, it is well to bear in mind that the term is a tribute to the achievement of part of the upper stratum of society of that

day, the great mass of the people being little above the status of slaves. Only a small percentage of the total population enjoyed the comforts and enlightenment which are now extolled as representative of that period.

FURTHER POWER DEVELOPMENT AS EXEMPLIFIED BY THE UNITED STATES

The preindustrial era of colonial days in the New World. In order to picture clearly the tremendous progress which has been made in the past two centuries, it is helpful to consider the industrial conditions which prevailed during the period of British colonization in the New World. Manufactures were then almost entirely on a handicraft basis, and the equipment was simple indeed, as is shown by the fact that the shoe factories of those days were merely groups of cobblers in large rooms.

In any new country where contacts with the outside world are slow and difficult, men turn first to agriculture because they must eat to live and they must farm for food. In the colonial days of North America this tendency was further fostered by ready markets for the agricultural products and the availability of cheap land well suited for cultivation, especially in the area from present-day New York City on southward.

New England, however, was different in its agricultural aspects from the colonies farther south. Because of shorter growing seasons, more rigorous winters, and soils less easy to clear, she could not compete in general agriculture with her neighbors.

Shipbuilding and commerce were favored by the forest resources and the protected waters of New England, and both led to manufacturing, particularly of such articles as were needed for equipment or supplies for ships. Iron manufactures became important because even in the days of wooden ships much iron was needed for rods, bolts, and rivets. Massachusetts became the leading iron-manufacturing colony and remained so for more than a century prior to the American Revolution. Cooperage became a prosperous industry because of the timber readily available and the market furnished by the demand for barrels to be used in ocean freightage.

Manufactures which made use of imported cheap raw materials constituted another phase of industry to which New England naturally turned. Illustrations are found in the refining of crude sugar which was brought back from the West Indies and in the manufacture of rum from the molasses which was obtained chiefly in the islands of tropical America, a manufacture not unimportant at a time when ships' allotments of rum for the sailors were deemed as necessary as the allotment of bread. Fish oils were sources of illuminants and lubricants, and therefore the refining of such oils became important.

For many of the early manufacturing activities power was needed, in fact it was necessary for a high degree of success. In this regard, New England was favored by numerous ponds and marshes out of which flowed streams characterized by a comparatively uniform flow and interrupted by stretches of rapids and low waterfalls. Near these stretches of greater stream gradient it was easy to construct small dams so as to create permanent, reliable differences in water level and lead the water from the higher level through a little canal, or millrace, to a water wheel. Such water mills, typical of early power developments, were used to saw timber into lumber, to grind grain into grist, to make paper, and for carding wool, fulling, and other purposes. Before the day that huge dams and generation of electricity became technically possible, the water mills provided the power resources which, although small, were well distributed over all of New England. A good example of such distribution is Fig. 211, a map of central Massachusetts in 1830, which shows the widespread development of small water-power resources at that time.

Among the mills on the map are a number of woolen and cotton mills. Many of these mills in New England were small because of the small amount of available power. However, larger mills existed along the lower courses of streams where more

WATER MILLS, WORCESTER COUNTY, MASS.

1830

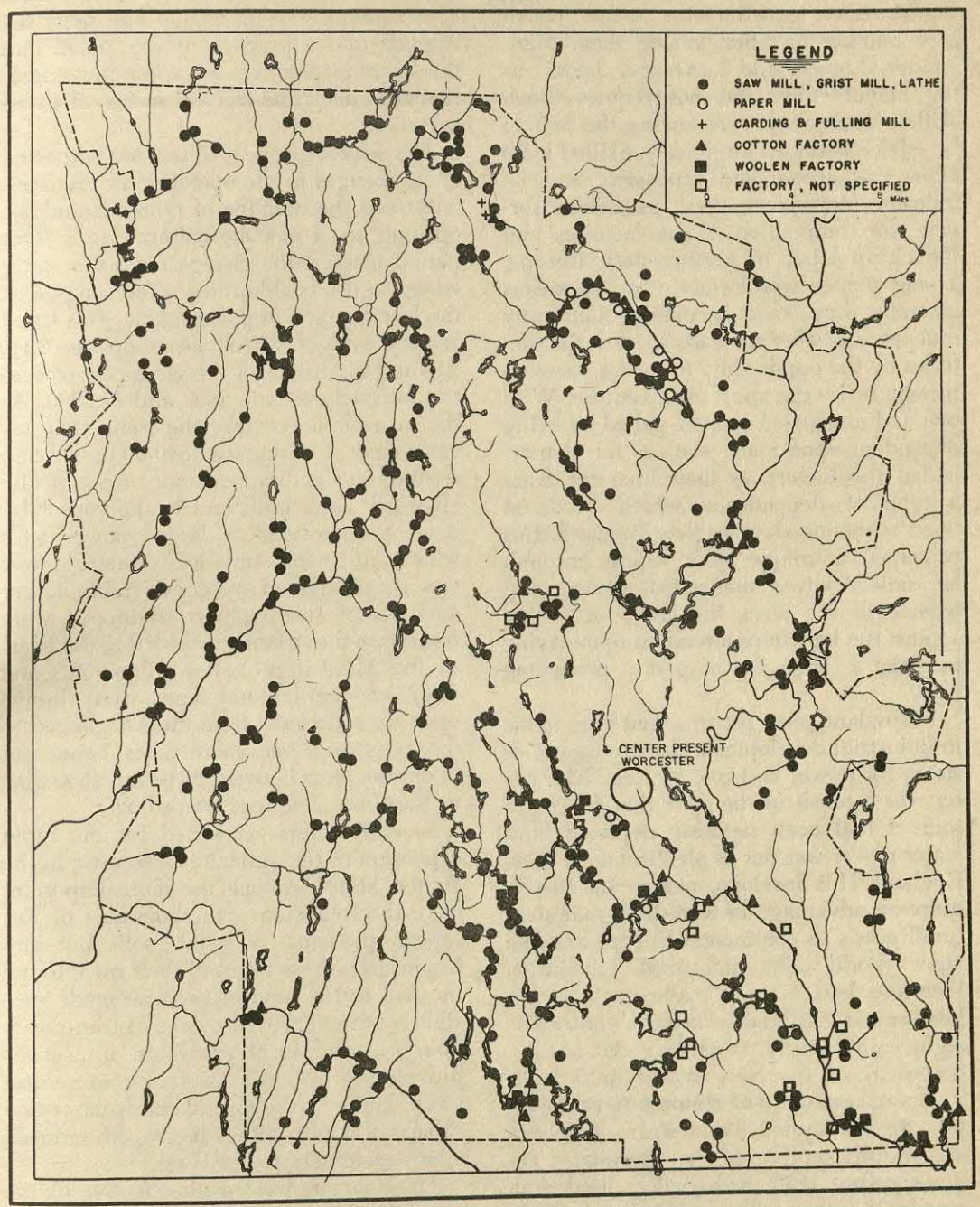


Fig. 211. Map of water-power plants in operation for mills and factories along the small streams of Worcester County, central Massachusetts, in 1830. Note the numerous plants and their general distribution over the county. What must have been true of the relative sizes of the power plants and mills?

power could be generated, as along the Merrimac river. The developments along the Merrimac gave impetus to the growth of a number of cities, among them Manchester, Lowell, and Lawrence. Since cotton manufactures did not require much skilled labor, they were among the first to be established on a large scale. Skilled male labor was scarce and expensive, and no industry dependent upon it could survive the competition of the factories and the cheap labor of northwestern Europe. Young women who formerly had no means whereby they could become economically independent were soon attracted to the factories by the opportunity to earn a personal income or by the spirit of adventure. Widows and unmarried women, galled by being dependent upon male relatives for charity, hailed the factory as their liberator from a type of dependency which bordered upon economic slavery. New England thus presented a unique labor supply through her sailors' wives, unmarried women, and women of the farm, the latter struggling against the hardships attendant upon trying to make a living out of poorly producing land.

In England more progress had been made in industrial development due to the use of steam for power and coal for fuel. The latter was a result of the facts that forest resources had been seriously depleted, and water power was not as plentiful as in New England. This development gave the British quite an advantage in furnishing manufactured goods to continental Europe and the New World. The Industrial Revolution therefore had already made considerable headway in England before the end of the eighteenth century, whereas it did not get underway in the New World until later.

The ascendancy of steam power, 1840-60. In the United States steam had been successfully employed in stationary engines before 1830, with boilers fired with wood rather than with coal. Gradually, however, coal became the principal fuel.

Although prior to 1840 the manufacturing industries of the United States employed a comparatively small percentage of the population, several of the major groups, particularly cotton, wool, leather, and iron, had become firmly established. The stationary steam engine had been developed into a practical power plant, and the steam locomotive was winning recognition as a quick and efficient means of transportation.

The decades from 1840 to 1860 witnessed great changes in the operation of factories, witnessed the building of railroads and the opening up of new agricultural lands. This period marked the change from the water wheel to the coal-burning steam engine as the leading type of power plant. This trend is very evident when one compares Figs. 211 and 212, maps of the same part of central Massachusetts in 1830 and in 1900. By the turn of the century the trend that became evident during the 1840-60 period had resulted in the disappearance of practically all small water mills and in the consolidation of operations at larger power sites where in many instances water power was supplemented by considerably larger amounts of steam power. Railroads were built from the Atlantic seaboard to the heart of the Mississippi Valley (Figs. 213 and 214), and agricultural lands were thrown open for settlement from the Alleghenies to the Missouri river, more acres being put under the plow between 1840 and 1860 than in the three centuries preceding.

Several factors accounted for the rapid expansion of the agricultural frontier in the United States. Among the more important were the following: (1) thousands of European peasants, poor in goods but ambitious to possess farms of their own, found the trip to the land of promise made possible by the improved means of transportation; (2) industrial expansion in Europe provided growing markets for American grain; and (3) the lure of the frontier and rumors of readily attainable wealth induced many easterners to go West.

These factors were made effective by the existence of extensive grasslands west of Indiana and by the new railroads. The expansion of agriculture which characterized the period from 1840 to 1860 could not have occurred had the coal-burning steam engine not been adapted to efficient transpor-

TEXTILE FACTORIES, WORCESTER COUNTY, MASS.
1900

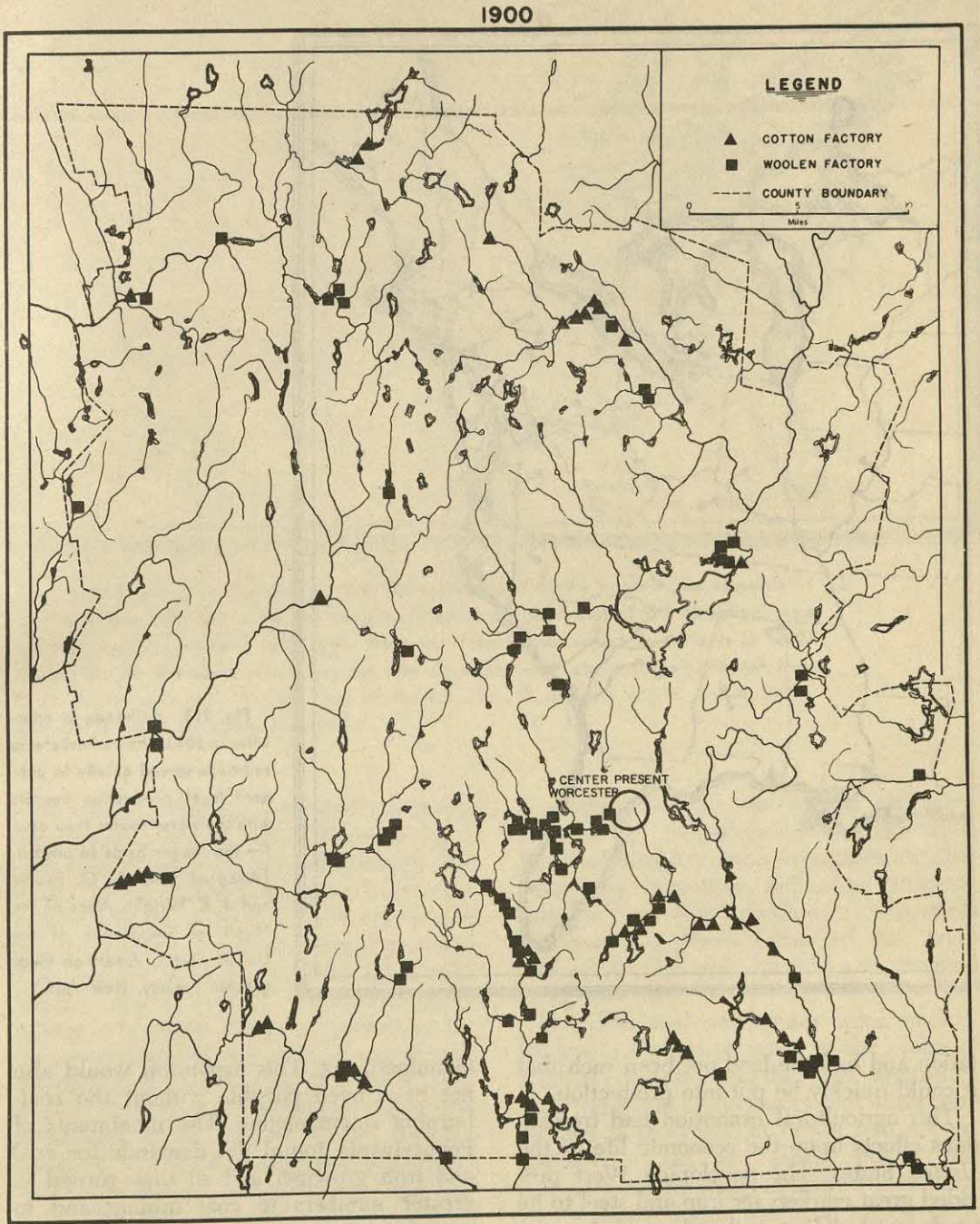


Fig. 212. Location of principal cotton and woolen mills in Worcester County, central Massachusetts, 1900. Consolidation of operation into larger power units, water-power and steam plants, is evident. Note contrast in pattern as compared with that in illustration on p. 329.

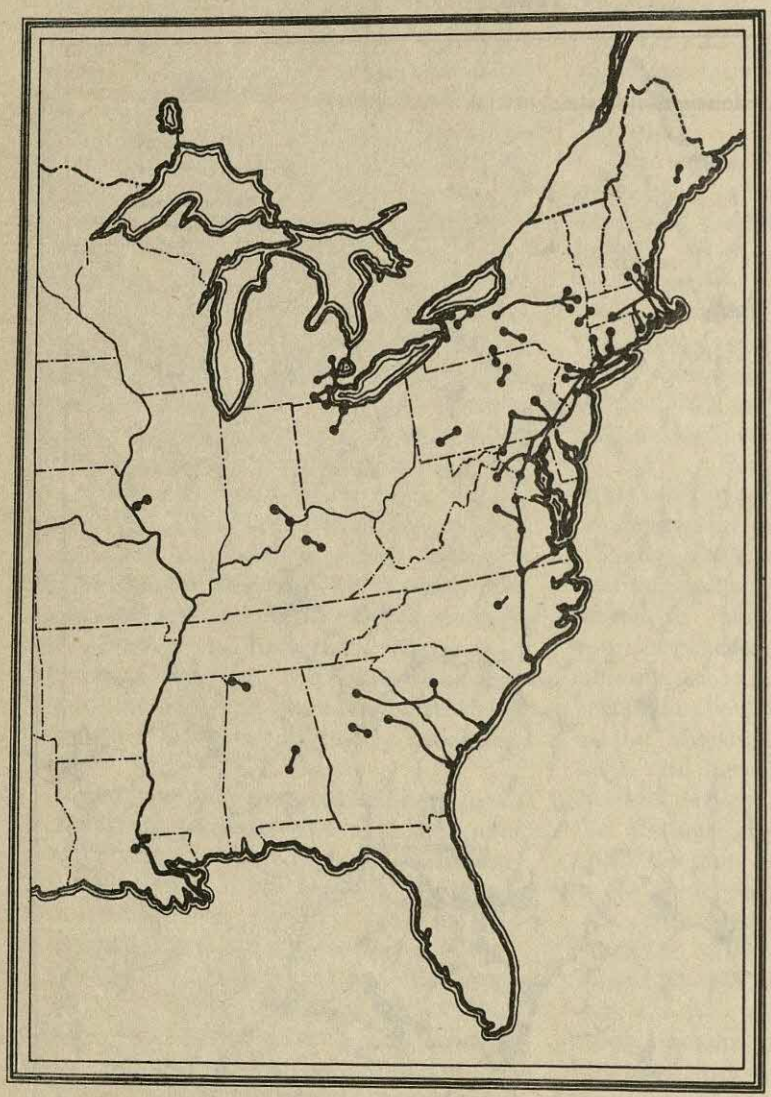


Fig. 213. Railroads in operation in 1840. The earliest steam railroads served chiefly to connect local production centers with the water routes then used for the longer hauls to market. (Adapted from C. O. Paullin and J. K. Wright, Atlas of the Historical Geography of the United States, American Geographic Society, New York.)

tation and had the land not been such that it could quickly be put into production.

This agricultural expansion had tremendous effects upon the economic life of the United States. The developing West provided great markets for iron and steel to be used for building railroads and for the manufacture of farm machinery and household necessities. The increasing population gave rise to steadily expanding markets for manufactured goods. As New England found agriculture becoming increasingly unprofitable, her people turned more and more to manufacturing. This expansion would also not have been possible without the coal-burning steam engine. The inhabitants of Pennsylvania found the demands for coal and iron growing, and so they turned in greater numbers to coal mining and to manufacturing.

The importance of capital and inventiveness. Of course, the great changes discussed above should not be ascribed exclusively to the availability of a major source of power. They would have been impossible if capital had not been available

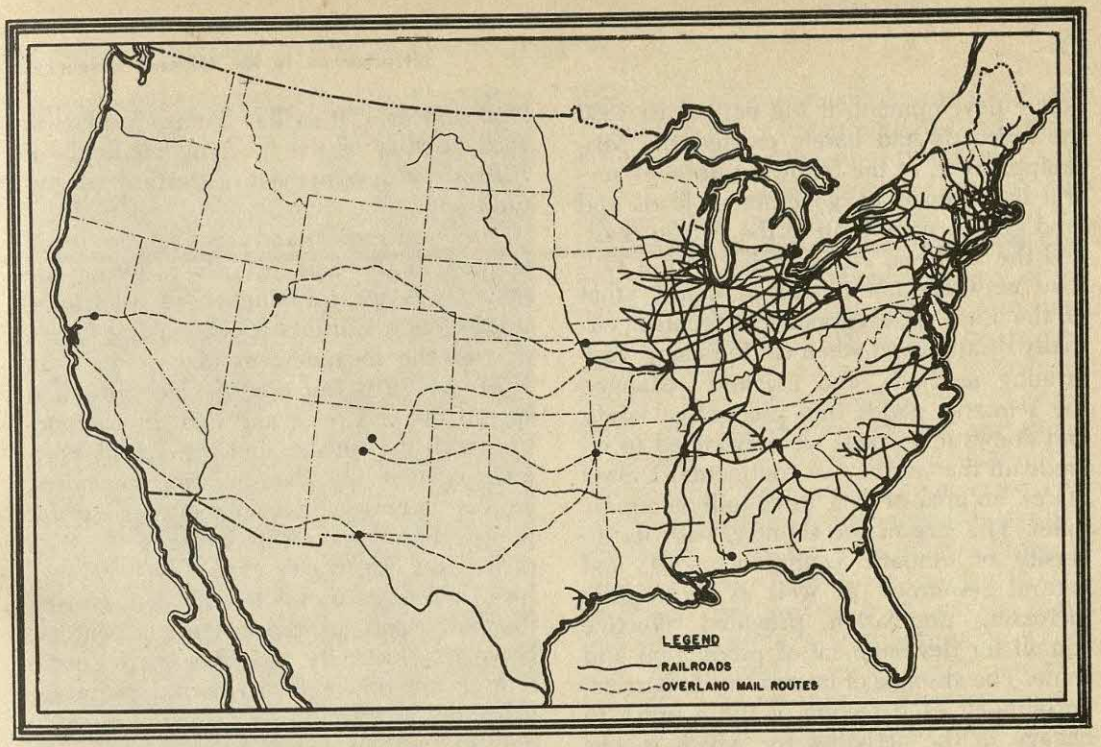


Fig. 214. Railroads in operation in 1860. The railroads had barely begun to be consolidated into systems in 1840, but in the two decades following the lines east of the Mississippi were operated largely as systems. What were the most western cities served by railways in 1860? The pattern for the whole nation was not fully developed until about 1885. (Adapted from C. O. Paullin and J. K. Wright, Atlas of the Historical Geography of the United States, American Geographic Society, New York.)

with which to finance the rapidly expanding railroads and factories. Fortunately, a nest egg of capital, earned through the profits of ocean shipping, gave liberal returns when set to work in industry during the early part of the nineteenth century. This success went far to establish credit abroad, and European investors became willing to furnish money at moderate returns on reasonable securities. Furthermore, the output of gold in California after 1848 furnished much-needed capital during the latter part of this period. Money became plentiful, and interest rates were relatively low. With capital on hand, with raw material abundant, and with markets expanding, the manufacturing industries could grow rapidly.

Man had to do his part by inventing further types of labor-saving machinery. When labor is comparatively scarce it becomes costly, and man then becomes interested in utilizing it with the utmost efficiency. Thus arises the incentive for invention. American and European inventions together effectively promoted industrial progress, and the New World with its rich rewards for inventive genius furnished the larger part of the economic incentive to progress along this line.

By 1860 coal and steam were unchallenged in their supremacy in the realm of applied power because they had vanquished their industrial predecessors, and other competitors in the realm of power had not yet appeared. Coal and steam power had caused a far-reaching industrial revolution in the United States, while, during the same period, there occurred the greatest agricultural expansion that the world had ever experienced.

The supremacy of steam and the advent of electricity, 1860-1910. This half century was marked by the rapid eco-

nomic development of the nation. In 1860 the railroads had barely crossed the Mississippi river; in the following decades several lines, aided by government loans and land grants, were built to the Pacific coast, and the Midwest was supplied with a railroad network that rivaled in density that of the East. The agricultural frontier virtually disappeared when cattle raising, dry-farming methods, and irrigation changed the semiarid plains into productive lands, and domestic markets were extended to include all the territory of continental United States, an area of over three million square miles. The size of the country, with its diversity of climatic conditions, soils, and natural resources, as well as its rapidly increasing population, provided effective stimuli for development of production and trade. The absence of internal trade barriers encouraged each section of the country to engage in the activities for which it was best suited and to exchange its surplus products for needed goods from other sections.

Among the changes wrought in the period 1860-1910, perhaps none were of more profound economic and social significance than the greatly increased industrialization. In 1860 the United States still ranked so low in manufactures that it was of little consequence as an industrial nation; by 1910 it had become one of the world's leaders in manufacturing. The growth had been so gradual that few people sensed its import. Manufactures had expanded chiefly in response to the growing home demands, and the entry of American manufactured goods into world markets on a large scale had barely begun.

Tremendous as the growth of industry was during this half century, the power it used was not highly mobile. Steam had to be used where generated. The boiler had to be operated near the engine, and from the engine power could be transmitted only by means of a belt to a nearby pulley shaft.

An event of major significance during this half-century period was the introduction of petroleum as another source of power. The expansion of production from that of the first well, drilled by Colonel Drake near Titusville, Pennsylvania, in 1859, to that of the far-flung oil fields of 1910 was a development of startling magnitude.

The most radical and far-reaching development in the field of power during the period was the introduction of electricity, starting with Edison's epoch-making invention of the incandescent electric light in 1879. By 1910 the use of electricity had spread far and wide and had, in conjunction with the turbine and the use of Portland cement for dam-building purposes, led to renewed development of water power, but on a much larger scale than previously. Electricity gradually became a form of power useful to industry. During the early part of the twentieth century, however, electricity was little more elastic than steam power for industrial purposes, inasmuch as it could be delivered cheaply only to areas of compact population. As a consequence, both steam power and electricity were then conducive to concentration of industry in certain favorable areas.

The age of distributable power, 1910 to the present. Until about 1910 factory development tended to create small, excessively compact industrial districts around nuclei of available power and in or near great markets. In the years immediately following, the first long-distance transmission of electricity became practicable, followed by quick transportation over even much longer distances of crude oil, gasoline, and natural gas. Since 1910 extensive networks of high-voltage lines, through which electrical power is distributed over a large part of the country, have been constructed in the United States. Also, extensive pipeline networks have been created for the distribution of petroleum products (Fig. 215).

The fact that power and the raw materials for generating power can be distributed more easily and over longer distances is making possible some decentralization of industry, which, in turn, may prevent undue congestion of population, thus increasing well-being in general.

Other fundamental changes since 1910 include the universal use of trucks and auto-



Courtesy Standard Oil Company of New Jersey

Fig. 215. One of the modern ways of distributing power. The path of a pipeline through the woods near Fluker, Louisiana. Once buried, the pipeline leaves little mark on the landscape except its cleared right-of-way and its occasional valves or stations. Here a linewalker is clearing weeds from around a valve.

mobiles, the adoption of airplanes as commercial carriers of freight and passengers, and the inauguration of the first steps toward utilizing atomic energy. We cannot yet measure the effects of the latter, but it is possible that the ultimate results may allow some further decentralization of industrial plants.

FUNDAMENTAL RESOURCES ESSENTIAL TO INDUSTRIAL PROGRESS

When man succeeded in tapping large sources of natural energy, the way was open to elimination of much human drudgery. Man must, of course, continue to labor, but now his province lies essentially in directing machine activity instead of functioning personally as a primary source of power. The emancipation of man from the toil and inefficiency of earlier ages and his attainment of high per capita productivity are fruits of our power-machine economy. Fundamental to this economy is the utilization of the great sources of energy: coal, petroleum, natural gas, water power, and, perhaps within the near future, nuclear energy on a commercial, i.e., competitive, basis. The energy from these sources, converted into power and applied to raw materials through machinery, does the work of the times. It is to be expected that these trends will continue and that the zenith of material progress will be attained in due time, provided that the attendant social and economic problems will be solved. It seems imperative, therefore, that if harnessed power, made available in its distributable forms, is to serve mankind well, it must be made available to people everywhere. If such be possible, it may be truly said that, through energy available and applied as distributable power, there can be furnished food, clothing, shelter, and the comforts of travel and luxuries such as no people, not even those of the wealthiest classes, were privileged to enjoy in the past.

For discussions of the major power minerals, see Chapters 20 to 23. For discussions of the chief metallic and other mineral resources, see Chapters 24 to 27.

SELECTED GENERAL REFERENCES FOR CHAPTER 19 AND FOR CHAPTERS 20-27

Up-to-date statistical information on the production of and trade in mineral products in the United States and, to some extent, elsewhere in the world, will be found in:

Minerals Yearbook, Bureau of Mines, United States Department of the Interior, Washington, D.C., U.S.A. This yearbook appears annually in three volumes; one deals with metallic and nonmetallic minerals, except fuels; one, with fuels; and one treats mineral production by states of the United States.

The volumes for a specific year usually become available late the next year. The volumes contain no maps.

The Department of Mines and Technical Surveys of Canada publishes an annual review entitled, *The Canadian Mineral Industry*, which treats the various minerals mined in Canada and contains a number of maps.

A number of other countries publish annual or occasional reviews of their mining industries.

For detailed information on the United States, see also the volumes of the mineral censuses, published by the Bureau of Census, United States Department of Commerce, Washington, D.C., U.S.A.

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More technical and with emphasis on geologic aspects is:

Bateman, A. M., *Economic Mineral Deposits*, Second edition. New York: John Wiley & Sons, Inc., 1950, 916 pp.

Useful publications for further information on sources of energy are:

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New Sources of Energy and Economic Development. United Nations, Department of Economic and Social Affairs, New York, 1957, 150 pp.

Schur, S. H., B. H. Netschert, a.o., *Energy in the American Economy, 1850-1975: Its History and Prospects*. Resources for the Future, Inc., Washington, D.C., The Johns Hopkins Press, Baltimore, Md., 1960, 774 pp.

Thirring, H., *Energy for Man: Windmills to Nuclear Power*. Bloomington: Indiana University Press, 1958, 409 pp.

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Lovering, T. S., "The Exploitation of Mineral Resources," *The Scientific Monthly*, Vol. 68, 1949, pp. 91-95.

Wilson, M. G. A., "Some Population Characteristics of Australian Mining Settlements," *The Netherlands Journal of Economic and Social Geography*, Vol. 53, 1962, pp. 125-132.

20

Water as a Commodity and a Source of Power

ORDINARILY WE admire the clouds because of their ever-changing forms or because they remind us of sailboats carried to their destinations by strong and steady winds. We should admire them as evidence of one of the most essential transportation agencies known to man. Clouds consist of minute globules of moisture condensed out of the invisible water vapor always present in the air. Thus, quantities of moisture, as vapor and as clouds, are transported thousands of miles to be unloaded as rain, snow, or hail wherever conditions are favorable for precipitation.

Of the moisture that falls on the land much evaporates, but much soaks into the ground, and estimates made on the basis of extensive field studies indicate that 30 to 35 per cent of the rainfall becomes run-off water in brooks, creeks, and rivers. Part of what soaks into the ground becomes available to the roots of plants, but part goes deeper and joins the *groundwater,* a potential source of drinking and industrial water and even of water for agricultural purposes. The run-off, some of which is impounded into lakes at various altitudes, makes possible the development of water power and may also be used for domestic and industrial purposes. Although the major purpose of this chapter is to discuss flowing water as a potential source of energy, water as a commodity has become so important for domestic, industrial, and agricultural purposes that it should also be discussed briefly from the point of view of an economic good.

POROSITY AND PERMEABILITY OF ROCKS

The individual grains of quartz in a layer of sand are never so tightly packed but that tiny spaces are left between them, pore spaces or *voids.* Even when quartz grains are cemented together by lime, iron oxide, clay particles, or other cementing materials so as to form sandstone, the cementing material usually is in the form of a crust around each particle, so that there still are voids (Fig. 265). If one drops some ink or water on a piece of sandstone, it is likely

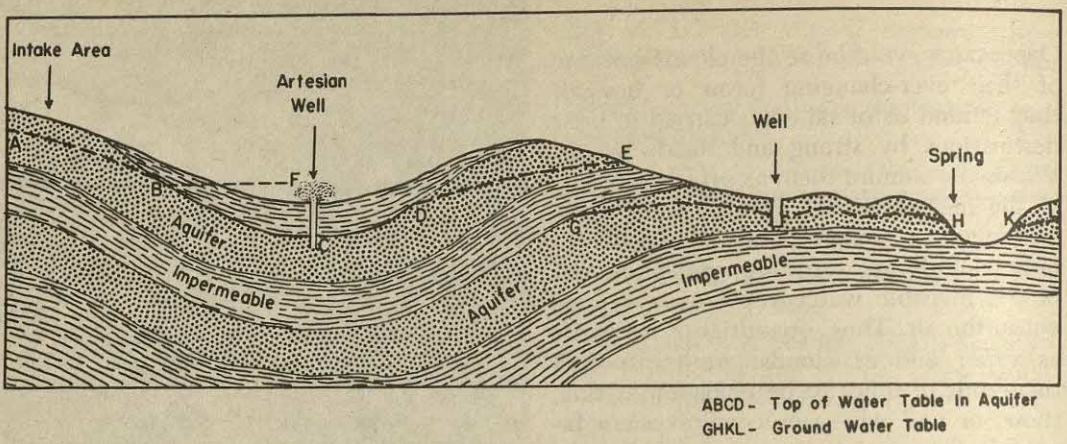


Fig. 216. Diagram illustrating the occurrence of ground water and of wells and springs.

to be absorbed as though by blotting paper. Loose sand and sandstone are porous, that is, they can absorb fluids. Even clay and shale are porous, but, as many of the constituent particles are submicroscopic, the voids are extremely small. At the same time these voids are extremely numerous. Rocks that are quite solid, such as granite and other igneous rocks, are able to hold fluids in the ever-present larger cracks called *joints,* and in so-called *hair cracks.* Also solid, nonporous limestones are able to hold water in joints and minor cracks. Metamorphic rocks, besides being jointed, usually can take in water along some of the *planes of schistosity.*[1] Thus porosity of rocks, or water-holding ability, varies greatly. Loose sands and clays may hold much water, a solid quartzite may hold very little.

Water in the voids and cracks is probably never entirely at rest. It can move with comparative ease through voids of sands or sandstones or through widened joints and other cracks in limestone. Such rocks are called *permeable.* On the other hand, water movement is extremely slow through the submicroscopic voids of clays and shales. Such rocks are called *impermeable,* and for all practical purposes it may be said that water and other fluids, such as crude oil, do not move through them. Layers of shale, though full of water, if occurring on both sides of a sandstone, for example, will effectively seal off the sandstone and limit the movement of any fluids present in the sandstone.

[1] Schistosity refers to pseudostratification in metamorphic rocks resulting from great pressures during metamorphosis.

GROUND-WATER RESOURCES

It is clear that it is easiest to extract water from a porous and permeable rock such as sandstone and most difficult to extract it from clays or shales. Thus sands and sandstones are good *aquifers,* i.e., water- carrying strata or "water horizons," as are also gravels and conglomerates. If one digs a hole through the mantle rock into the bedrock and reaches a layer of sandstone, the hole, or *well,* may fill with water pure enough to be suitable for drinking and other purposes. This ground water may have entered the sandstone some distance away as rain water seeping down, and as it moves through the sandstone laterally it is naturally filtered, or purified. Of course, if the sandstone has iron oxide in it, the water may get a metallic taste, or if there is much lime in the sandstone the water may take this into solution and become "hard." If one takes water out of the well, usually other water filters in fairly quickly from the sides or bottom, as sandstone is permeable. A well in shale might give a little water that is not clear, and replenishment would be slow. In other words, the well would tend to run dry quickly (Fig. 216).

Strata from which it is easy to obtain water may lie at the surface or at shallow

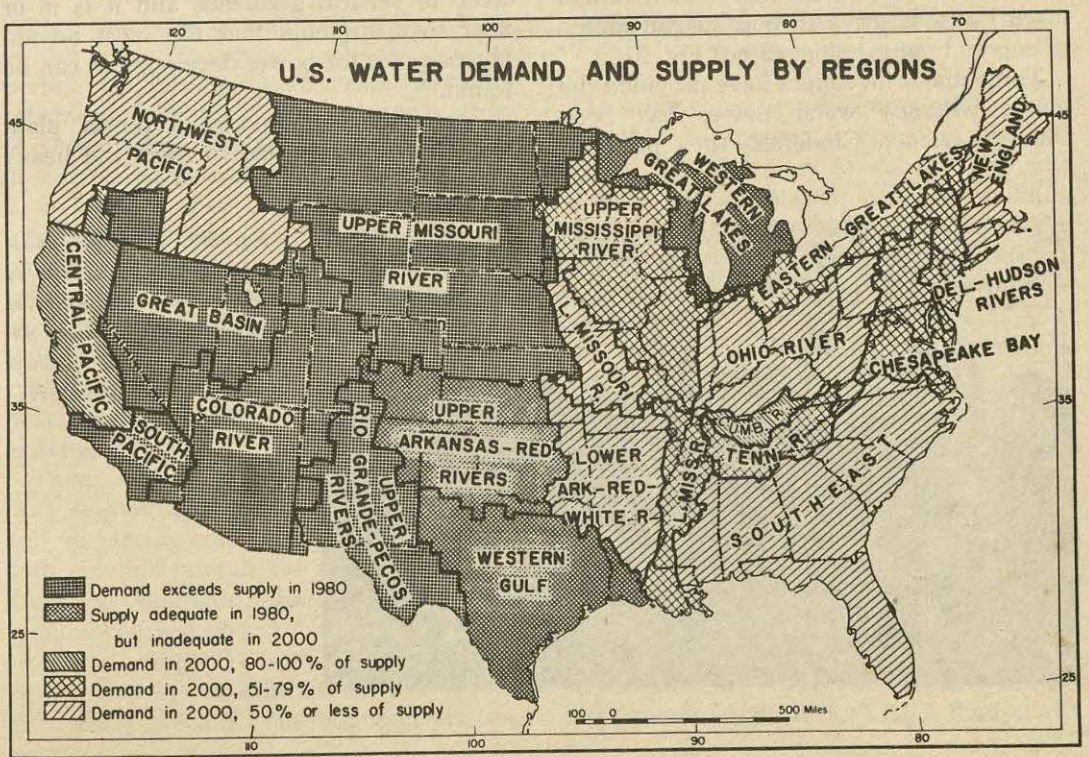
depth, as in fairly thick mantle rock, but also at such depth in bedrock that the water has to be reached by deep drilling and is sometimes even warm from the interior heat of the earth. Sand-dune regions may hold considerable amounts of water. In Western Europe certain coastal dune areas are used as source areas of drinking water for large cities. Even in dry regions dune areas will retain considerable amounts of ground water. This is true, for example, for the extensive Nebraska Sandhills Region and even for the *ergs* of the Sahara Desert.

Ordinary farm wells are able to tap aquifers fairly close to the surface, but deep drilling is necessary to reach lower aquifers. Sometimes water reached by deep drilling may come to the surface under pressure. These are so-called artesian wells. The pressure is caused by the area of intake of the aquifer lying higher than the top of the well (Fig. 216). In most cases, however, deep wells are not truly artesian, and the water must be pumped to the surface. Wells of these types may be drilled for water supplies for towns, for irrigation purposes, or for industrial purposes.

As our cities have increased in size, and as modern conveniences have required the use of more and more water, drilled wells have not been able to furnish sufficient quantities of water, and it has become necessary to create large reservoirs or to take increasing quantities of water from large rivers. Many modern industries are also heavy users of water, for cooling and many other purposes.

Thus the maintenance of an adequate supply of water for various purposes has become a problem, not only in drier areas but even in humid regions, such as many densely populated parts of eastern United States. Of course, in comparatively dry regions the problem is ever present, particularly if there are extensive urban agglomerations with industrial development. This is the case, for example, in southern California, where an adequate water supply must be maintained for agricultural, domestic, and industrial purposes. In other areas

Figure 217.



pump irrigation may easily lead to over-extraction of fresh ground water, with the result that deeper, more alkaline water, inimical to crop growth, may come to the surface. Thus, in recent years, the United States has become quite conscious of the fact that over large portions of its territory, the climate is subhumid rather than humid, and that even in truly humid portions summer droughts may seriously deplete existing reservoirs. Ground and other water is a resource which will require more and more careful husbanding (Fig. 217).

STREAMS AS SOURCES OF POWER

Streams have long been utilized as sources of power because man early learned to make a simple paddle wheel for the water to turn and so to do work. By such primitive methods only small amounts of water power could be developed. In order to render the flow more uniform and dependable, it was necessary to construct reservoirs, but these could not be large because the means of constructing strong, nonleaking dams had not been discovered. No wonder that with the advent of the steam engine man turned to coal as a larger and more elastic source of energy than running water (Fig. 218).

Three major inventions have provided the magic whereby water power has been changed from a Cinderella to a princess. The invention of the *turbine* made it possible to use much larger volumes of water and to increase greatly the height and therefore the pressure of the confined water column upon the blades. The invention of the *dynamo* made it possible to convert the energy of the falling water into electricity. The invention of *Portland cement* enabled man to construct dams hundreds of feet high and thousands of feet long by means of which even the largest rivers can be impounded safely. As a result of such inventions, hydroelectric power has, within the past fifty years, attained a status of considerable importance in most industrial countries.

Characteristics of streams favorable for water power development. The amount of energy contained in flowing water depends upon the quantity of water and the velocity of the current. The latter, in turn, depends upon the gradient of the stream. The Mississippi river in its lower course has a gentle gradient—its waters are sluggish, and the river does not offer as attractive possibilities for power development as does, for example, the rushing, turbulent Columbia river with its relatively steep gradient. Rapids and waterfalls indicate stretches of steep to vertical gradients, and it is in or near such stretches that the most advantageous sites for power development can be found.

For practical purposes, a power plant must not only be able to meet the heavy

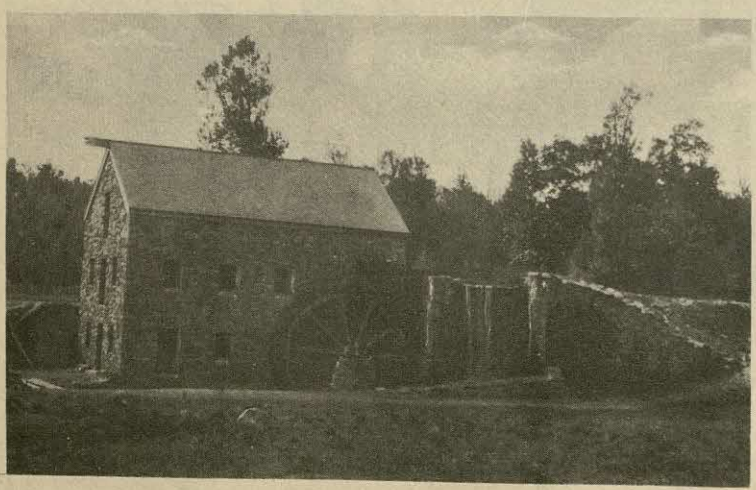


Fig. 218. Old water-power mill in Massachusetts, restored by Henry Ford. Mills of similar type provided most of the mechanical power for gristmills and sawmills until after 1815.

Photo by N. A. B.

demands of peak loads, which usually are of daily occurrence, but must also be able to furnish a steady, dependable amount of current, month after month. It is in the maintenance of steady energy production that water-power development encounters one of its chief problems, since most rivers are subject to pronounced seasonal fluctuations in volume. The Missouri river at Omaha, for example, has recorded a difference of nearly 20 feet between the high and low stages in a single year.

River regime. Observations of the quantity of water that from day to day flows past certain points along a river's course are of great practical importance. In the United States such observations are made by self-recording instruments along many streams and are collected and interpreted by the United States Geological Survey. As a result of the many years of observation, the average behavior of a stream over the course of a year can be calculated, showing low-water and high-water stages and rate of changes in water quantity. Such calculated average river behavior is called *river regime*. In its simplest form it is often shown as calculated mean monthly flow for each month of the year at one or more points along the course of the stream concerned. The longer the period of observation is—in years—the more reliable will be the monthly averages. It is, of course, very important to know the regime of a river before water-power development is undertaken. For example, the development of power from a stream characterized by a broad valley and great fluctuations in volume during the course of a year would necessitate not only dams of huge dimensions and great strength but also extensive artificial lakes for water storage. Power so developed would be limited in quantity and extremely costly.

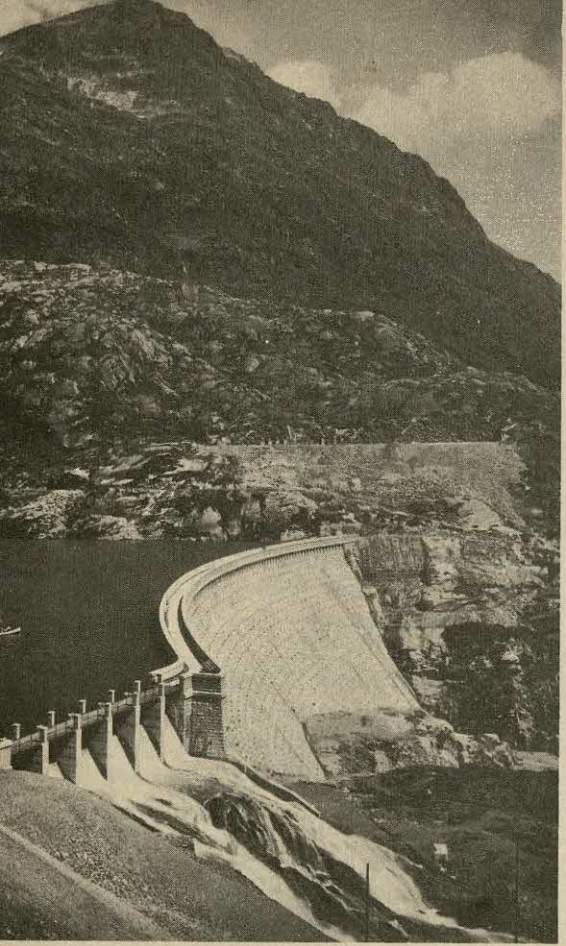
There is an intimate relationship between *river regime* and the climate, topography, and vegetation cover of an area. In regions with equable rainfall, the river regime will show less fluctuation than in regions with pronounced wet and dry seasons, as for example, the tropical savannas or the dry interiors of the continents. Rivers that derive most of their water from mountain glaciers are generally more dependable than those that obtain their water from precipitation in a lowland area. Rivers that flow through well-forested mountain regions have a more favorable regime than those flowing through mountain areas which have been deforested and where the surface litter has already been removed by erosion or burning.

The most favorable conditions for hydroelectric development would be near a waterfall with a great height of fall, on a river with a very large flow and a very equable regime. Unfortunately, such conditions are rarely encountered. Niagara Falls approaches them, with an impressive height of fall, a large flow, and a fairly equable regime, as the Niagara river is fed by a large natural lake, Lake Erie.

Where such favorable conditions do not prevail, a relatively small flow of water should be accompanied by a steep gradient, and where the gradient is more gentle, the amount of available water should be large. In both cases, any low-water stage should be counteracted by the creation of one or more storage reservoirs to serve during such a period.

MECHANICS OF DEVELOPMENT OF WATER POWER

In order to harness the energy of a stream and thus to convert it economically into power, it is necessary to stabilize the flow of water. This is accomplished by building a dam, in some cases hundreds of feet high, so that an area above the dam will become a reservoir to make available a dependable quantity of water regardless of seasonal rainfall fluctuations. The water is taken from the head of the dam to a plant near the foot, or it may be taken out of the storage reservoir via a power canal which follows mountain slopes for some distance until a suitable height of fall is obtained. In either case the water is led through a *penstock* at a very steep angle to a turbine. Pressure against the blades of the turbine causes revolutions which are transmitted to the dynamos for the generation of electrical power. Penstocks, whether vertical or inclined, are always much larger at the intake than at the



Courtesy Embassy of Switzerland, Washington, D.C.

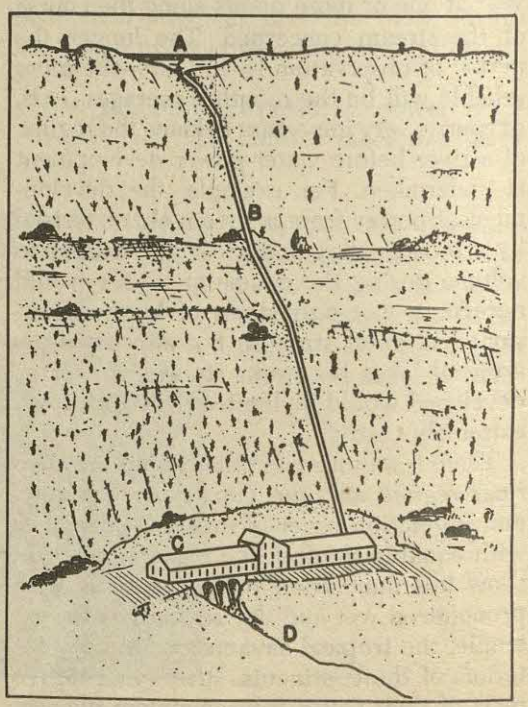
Fig. 219. The reservoir of the Barberine high-head water power development near Chatelard in the Valais, the valley of the upper Rhône River. The reservoir serves to equalize flow. From here the water is conducted to the upper end of the penstocks. See next picture.

outlet and are so constructed that any disturbance of the surface water of the reservoir above the dam will not affect the pressure of the water at the outlet of the turbine. This is, of course, necessary in order to insure steady generation of current by the dynamos. The pressure per square inch on the blades of the turbine is 0.433 pounds per foot of vertical distance from the surface of the water to the point where the water enters the turbine through the penstock.

Where power is generated at waterfalls, the water is taken out some distance above the falls and brought by canal to a penstock which leads to the powerhouse located near the bottom of the gorge which is generally present below major falls. At Niagara Falls, where power has been developed in this way, the power companies have constructed long intake canals and rock tunnels to carry the water to the penstocks. Unfortunately, diversion of the water sometimes impairs the beauty of the falls. In most cases, however, as at Niagara, a happy medium can be struck, satisfying both the requirements for power and the demands for the preservation of natural beauty.

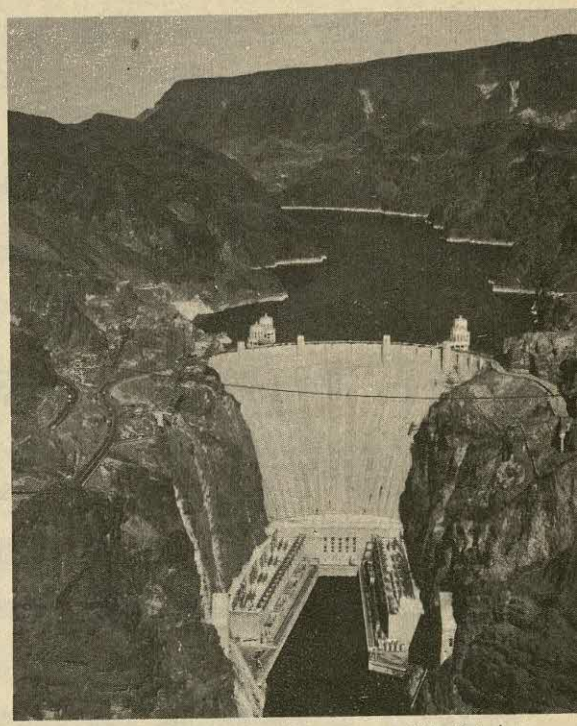
In mountain areas of the Alpine type the streams derive a fairly steady flow from the permanent snow and ice fields of the summit regions. These snow fields have often been referred to figuratively as "white coal" —a term now widely used for hydroelectric energy. Most mountain streams are relatively small, but usually man can easily con-

Fig. 220. Pen sketch of penstocks (B) connecting the Barberine Reservoir (A) with the turbines and generators in the power house (C). The water pressure is measured by the height of intake at A above the turbines in the power house. Water escapes below the power plant and forms the stream at D. (Sketch by Glenn Downey, Univ. of Nebraska.)



struct storage reservoirs in their upper reaches, and their gradients are so steep that he can utilize the pressure obtained by a drop from great heights to compensate for the smaller amount of water available. In the Alps and similar high mountain areas are some sites where the water descends from four to five thousand feet through penstocks before reaching the turbines at the base (Figs. 219, 220, 221).

In favorable cases, such as where a large stream flows through a deep and narrow canyon, man can create a veritable artificial Niagara. Such is Hoover Dam in the canyon of the Colorado river, 750 feet high and reaching from canyon wall to canyon wall (Fig. 222). Thus not only is great pressure created by raising the water to near the level of the dam, but also large enough quantities of water are made available to fill several penstocks.

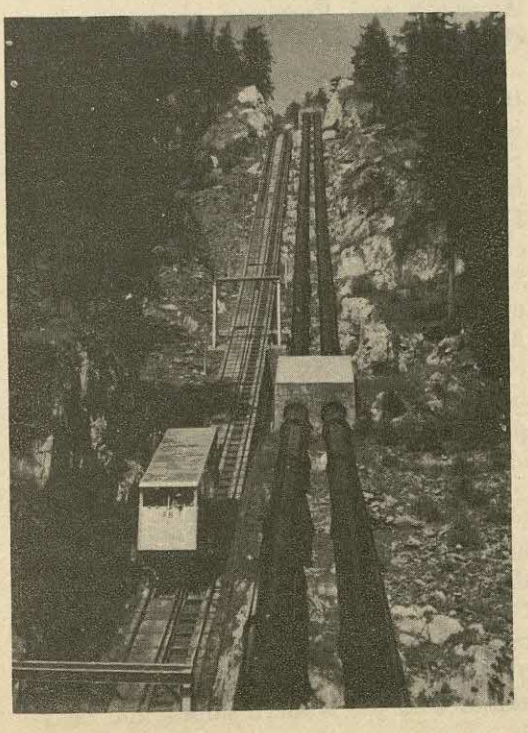


Courtesy Bureau of Reclamation, Department of the Interior

Fig. 222. Hoover Dam, an artificial "Niagara type" water power development. Lake Mead back of the dam, two power houses in the canyon in front. Fortification Mountain in the background.

Fig. 221. Close-up view of a section of the penstocks of the Barberine water-power development. The Barberine Reservoir is higher in the mountains, and the power house is further down the valley.

Courtesy Embassy of Switzerland, Washington, D.C.



In lowland areas, streams tend to be sluggish and broad, but they often carry large amounts of water. Man cannot raise the stream level to great heights by constructing dams across such rivers, but the large volume of water compensates for the lower fall. Examples of this type are the Keokuk Dam across the Mississippi and the Conowingo Dam across the Susquehanna (Fig. 223). This type of hydroelectric development is costly per unit of power produced unless associated with multiple uses such as navigation, irrigation, or flood control, and therefore to date the number of developed sites in this category has been relatively small.

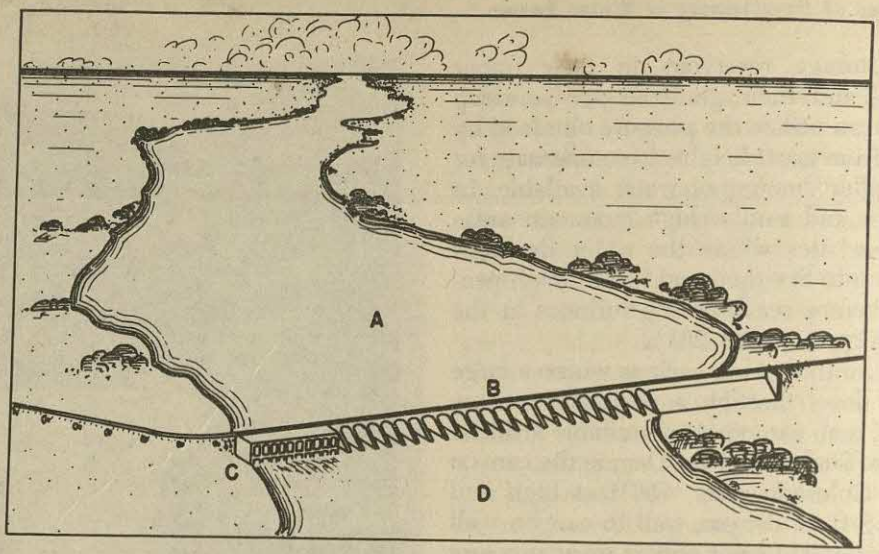


Fig. 223. Pen sketch of the Conowingo Dam (B) and power plant (C) on the Susquehanna River, Maryland. Developed head—drop from reservoir surface (A) to base of power plant (C) at water outlet downstream—is 89 feet. Compute pressure per square inch upon turbine blades. (Sketch by Glenn Downey, University of Nebraska.)

POTENTIAL WATER-POWER REGIONS OF THE WORLD

Outlets of large lakes. Where nature has provided storage basins in the form of lakes we find the most uniform type of river regime. Well-known examples of this type are the Niagara and the St. Lawrence rivers, both of which head in large lakes and are noted for their constancy of flow.

Formerly glaciated areas. The portions of North America, Europe, and Asia which were covered by continental glaciers during the Pleistocene period or "Ice Age" are characterized by streams that have many waterfalls, large and small, and frequent stretches of rapids or "white water." Thus there are many places where there is, or where there can be created, sufficient height of fall for hydroelectric-power developments of varying size. These regions also have many small and large lakes which help to create a more uniform flow of the streams. And where the lakes have disappeared in the course of time, the lake basins, often swampy, have remained, and by the erection of dams these can easily be made once again into lakes to serve as reservoirs and flow equalizers. Many existing lakes in New England, for example, whether used as reservoirs for drinking water or for power purposes, are such "re-created" lakes.

The Canadian and Scandinavian Shields, which are the respective former centers of American and European glaciation, have the largest potentials. Although in both areas precipitation is from low to moderate, the temperatures are not high, evaporation is low, and thus plenty of water is available. However, low winter temperatures persist for months, causing operational problems. During the cold months mean flow may be considerably reduced, and in very severe weather ice may form within the penstocks, choking flow to a greater or lesser extent. Also, ice masses may clog the outlet canals. Nevertheless, these difficulties ordinarily can be overcome through careful engineering planning without adding greatly to the cost of producing electrical current.

High mountain areas. Other areas favorable to hydroelectric development are high mountain areas, such as the Cascades, the Alps, the Caucasus, and the Himalayas. On most of these mountain slopes precipitation is heavy. In the Cascades it amounts to more than 80 inches per year at high altitudes on the western slopes, and in the

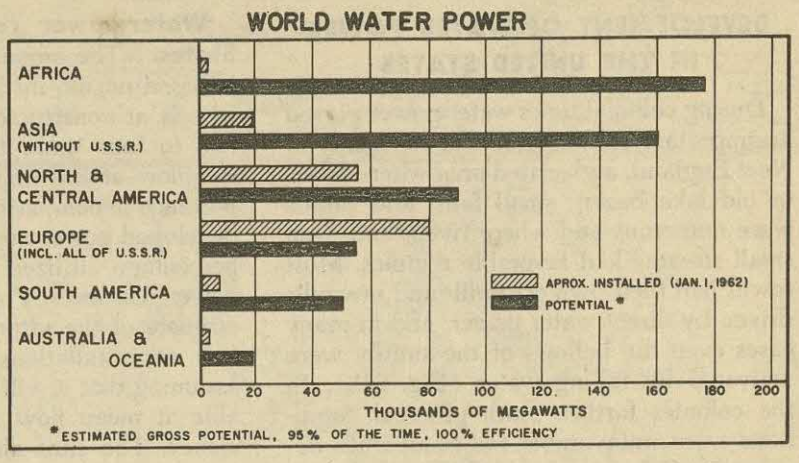


Figure 224.

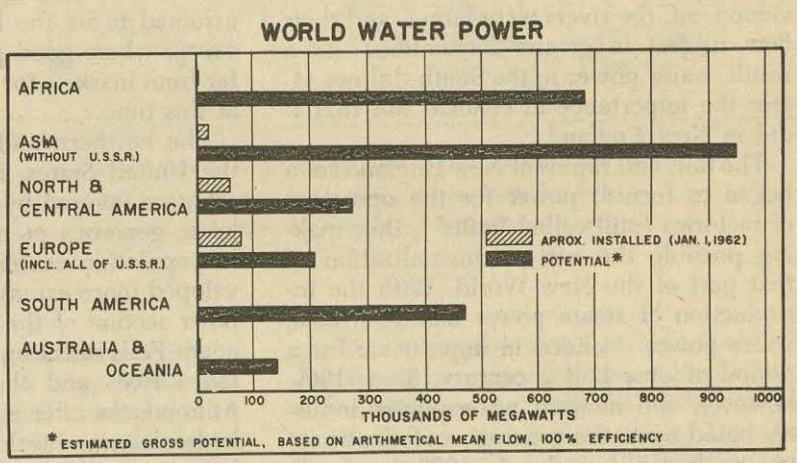


Figure 225.

higher parts of the Alps precipitation exceeds 120 inches. Rivers are well fed by snow fields and glaciers. Gradients are steep, and storage reservoirs either exist as lakes or old lake basins that can be reconstructed whenever necessary.

Rainy tropics. The tropical zones of high rainfall in South America and central Africa are rich in potential water power. Africa is especially well favored because much of the interior is a high plateau, and practically all the rivers have falls and rapids near the coasts. In South America the greatest power possibilities occur in well-watered portions of the Andes and along the "fall lines" which extend around the Brazilian and Guiana Shields. The large potentials of Africa and South America and the more modest potentials of southern Asia have been but slightly developed as yet because they exist either where population is sparse or where modern industrialism has made little advance. In Asia, Japan and Korea have made great strides in hydroelectric development. In South America, Brazil takes the lead, but the percentage of power so far developed is low in comparison with the total potential. Much of Australia is too arid to produce large quantities of water power, although portions in the east have heavy rainfall. It seems certain, therefore, that insofar as hydroelectrical development is concerned, North America and Europe will continue to hold first place for some time to come. (See World Map of Climatic Regions at end of book and Continental Maps which precede the text; see also Figs. 224 and 225.)

DEVELOPMENT OF WATER POWER IN THE UNITED STATES

During colonial times water power played an important role in America, especially in New England, a glaciated area where lakes, or old lake basins, small falls, and rapids were numerous and where rivers and even small streams had favorable regimes. Most towns had their own gristmills and sawmills driven by direct water power, and in many cases even the bellows of the smithy were activated by falling water (Fig. 218). In the colonies farther south physical conditions were unfavorable for small-scale development; the rivers were larger, and their flow subject to greater fluctuations. As a result, water power in the South did not attain the importance in colonial life that it did in New England.

The falls and rapids of New England soon began to furnish power for the operation of factories (still called "mills"), thus making possible the early industrialization of that part of the New World. With the introduction of steam power based on coal, water power declined in importance for a period of over half a century. Since 1900, however, the modern water-power industry based upon the generation of electricity has made rapid strides. In 1920 the developed water power in the United States was nearly 4 million kilowatts, and in 1960 it had reached over 33 million kilowatts. However impressive this increase may appear, it is important to keep in mind that it is estimated that of all power used in the United States—including, of course, that used up by cars—only four per cent is derived from water power. Water power in the United States has attained about 95 per cent of its potential, based on ordinary *minimum* flow. Based on ordinary *mean* flow, the potential would be more than three times as large. Thus with complete development of the water-power resources of the United States only about three times the present amount of hydroenergy could be generated. This shows conclusively that water power can never furnish more than a small portion of the total amount of energy required by the country.

Water-power regions in the United States. The amount of developed power is based on the installed capacity of water wheels at constructed plants and averages two to four times the potential power at low flow at the same sites. This is of importance in comparing potential power with developed power and also in estimating the percentage utilized of a nation's water-power resources. For any country a rough estimate of the *ultimate* attainable production at installations can be obtained by assuming that it will equal the power available at mean flow and 100 per cent efficiency. The sites already utilized may be assumed to be the best sites in a country, except where good power sites may be too far from markets for economic development at this time.

The northern and northeastern parts of the United States, from Maine to Minnesota, are favored by numerous streams and lakes, generous precipitation, and nearness to population centers. Water power is developed more extensively there than in any other section of the country. As a unit Niagara Falls ranks supreme, but the St. Lawrence river and the tributaries from the Adirondacks offer many favorable sites for hydroelectric development. In the region between Buffalo and Niagara Falls to the west, and the upper Hudson river to the east there are a number of major hydroelectric developments. Even in this favored area, however, hydroelectric power is insufficient to meet the demands and must be supplemented by a number of large steam plants, powered by coal, to provide the needed even flow of electric power (Fig. 226).

Another well-known site, now fully developed, is that of the St. Anthony Falls in Minneapolis, where the great flour mills were early favored by hydroelectric power. At present the most important function of the water power here is to provide supplementary current to meet daily peak loads (Fig. 227).

The Appalachians from Pennsylvania southward to Alabama constitute another water-power region, one which attains maximum potentiality in North Carolina and

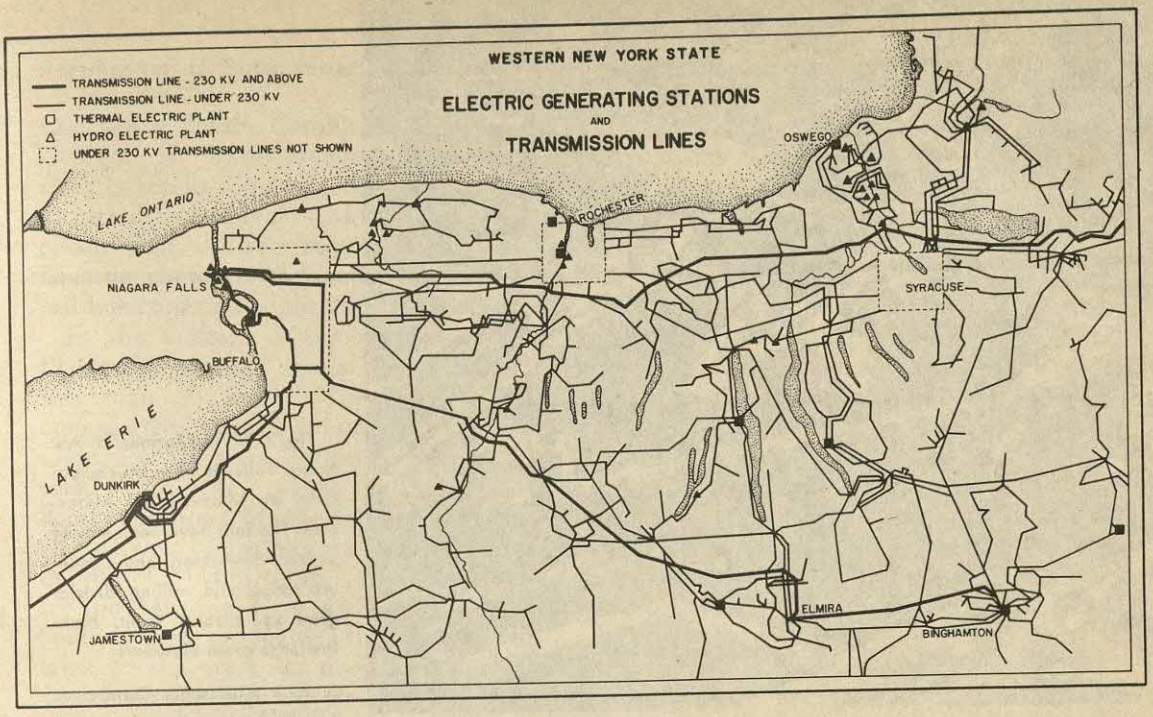


Fig. 226. A map showing modern distribution of hydroelectric and thermoelectric power. The minor lines for final distribution to farms and city homes cannot be shown. Note that even in an area of abundant waterpower, thermal electric plants are a necessity for balanced energy flow.

Tennessee, where the mountains reach altitudes of from 4,000 to over 6,000 feet. Rainfall is abundant there, averaging from 60 to 80 inches per year. Numerous streams of large volume and with steep gradients descend from the mountains to the adjacent lower lands of the Great Appalachian Valley to the west and the Piedmont to the east, where population is relatively dense, and the need for power is great.

On the west side of the mountains the Tennessee river basin has become a major, highly developed water-power region. Under the auspices of the Tennessee Valley Authority, the development is of the multiple-purpose type: it is a unitized program involving flood control, water-power development, land-use improvement, and improvement of stream navigation. These are made possible by dams which impound the water and reduce the great differences between high- and low-water stages characteristic of the streams of the area. The impounded water is used for the generation of electricity as it is discharged into the streams for the purpose of improving navigability during low-water periods. This has also made necessary reduction in the rate of run-off from the slope lands drained by the Tennessee and its tributaries. In order to accomplish this phase of the conservation program, an energetic educational campaign has been and is still being carried on whereby grain and livestock farmers are fully informed concerning the wisdom and economic soundness of a program of soil conservation that includes terracing, improvement of grass and timber cover, and the choice of crops, all employed to reduce to the minimum the loss of soil by running water. Inasmuch as the program is one of multiple objectives, only part of the total cost of impounding the river waters into lakes by means of dams is chargeable against the hydroelectric power generated.

East of the Appalachians, beyond the mountains proper, the streams pass abruptly from the hard rock of the Piedmont to the soft rock of the Atlantic Coastal Plain. Above this line of contact, in the so-called fall-line zone which extends from Trenton, New Jersey, via Baltimore and Richmond to

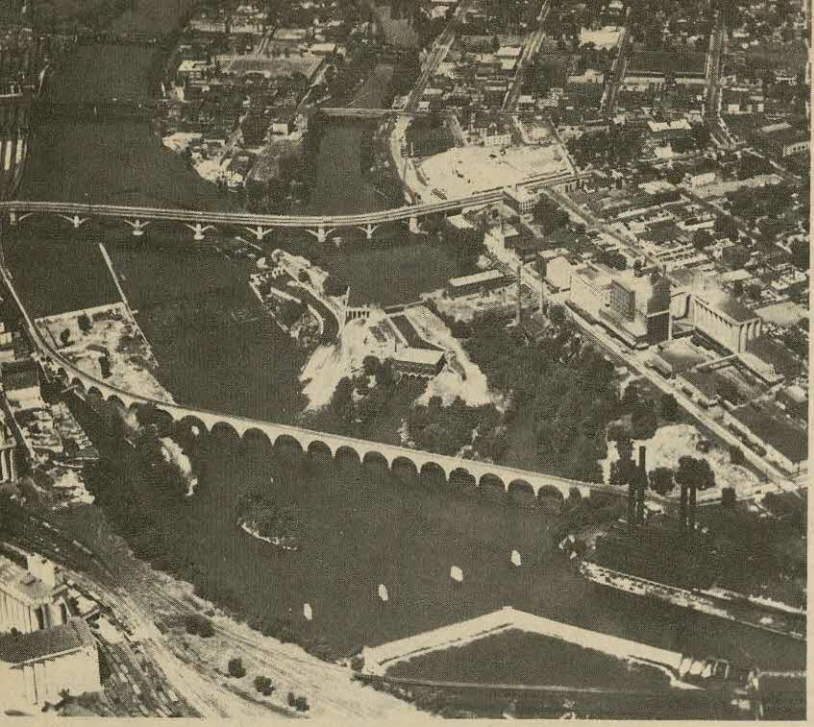
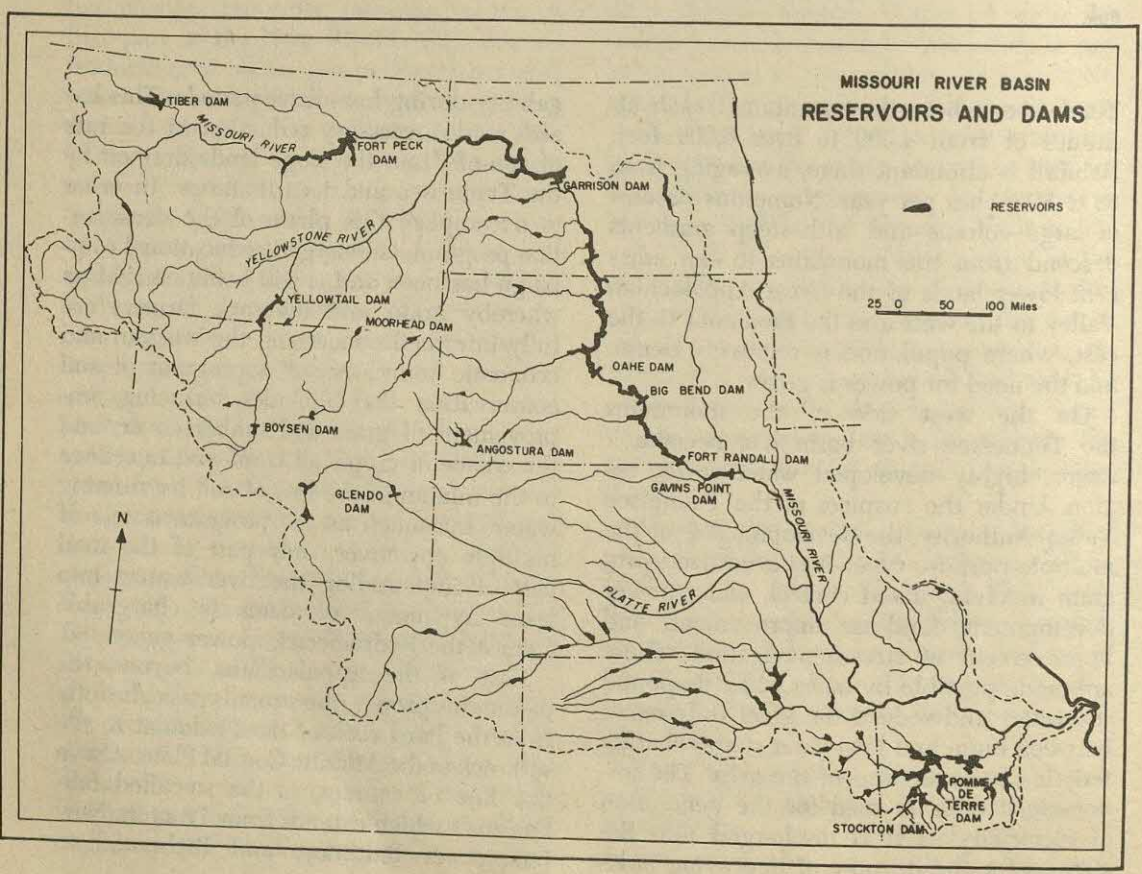


Fig. 227. The former St. Anthony Falls in the Mississippi river at Minneapolis, Minnesota. The falls have been almost entirely developed, and a manufacturing and milling district grew up around them. Note the large grain elevators.

Courtesy Minneapolis Chamber of Commerce

Figure 228.



Columbia, South Carolina, and Macon, Georgia, are some excellent water-power sites. In recent years large textile industries, attracted by available hydroelectric power, cheap labor, and proximity to raw material, have developed in the southern part of the fall-line zone and on the adjacent Piedmont.

In the western section of the Interior Plains the average annual precipitation is less than 30 inches. The streams have comparatively small volume during many months of the year, but are subject to seasonal high-water stages and occasional flood conditions. Much of the area north of an east-west line approximately through the middle of Missouri and Kansas is drained by the Missouri river and its tributaries. Some of these originate in the Rocky Mountains to the west, as does the Missouri; others, usually with less steady flow though occasional high-flood stages, originate in the High Plains. A comprehensive program to develop the Missouri river basin was started in 1946 and is still in the process of being completed. The purpose of the program is better control of flood conditions by the creation of many small and large reservoirs, the development of irrigation in a number of areas suitable for this purpose, better protection of riverine agricultural lands by means of levees, and some improvements in navigation. A number of large dams have been constructed on the Missouri river, and certain of its tributaries can furnish hydroelectric power to an area which, although not densely populated, has had an increasing need for power due to the mechanization of various aspects of farming, an increasing demand for air conditioning, the development of pump irrigation, and other purposes. The major dams are Fort Peck, Garrison, Oahe, Big Bear, Fort Randall, and Gavins Point. The reservoirs above these and other dams will be capable of storing maximum anticipated flood flows in the upper Missouri basin, and the hydroelectric plants will have a combined installed capacity of over two million kilowatts (Fig. 228).

Potential water-power resources of the United States are greatest in the Northwest. The western slopes of the high Cascades, which face the moisture-laden air masses that come from the Pacific, are noted for heavy rains and winter snows, the latter alone exceeding 30 feet in some years. The Grand Coulee and the Bonneville projects along the Columbia river have added power available from rain and snow falling on the American and part of the Canadian Rockies farther east. Of the total amount of potential water power in the United States, in-

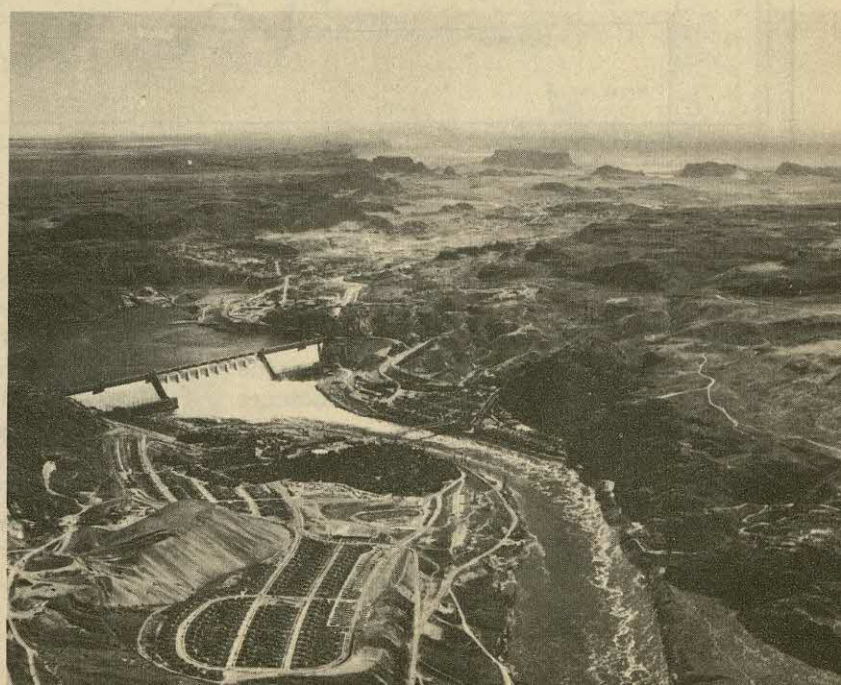


Fig. 229. Grand Coulee Dam, one of the largest concrete dams in the world. Note the two power houses at either end below the dam. The town of Coulee Dam in the foreground. Above the dam, to the right and fading into the distance past the mesas, is Grand Coulee, an Ice Age channel of the Columbia river.

Courtesy Bureau of Reclamation, Department of the Interior

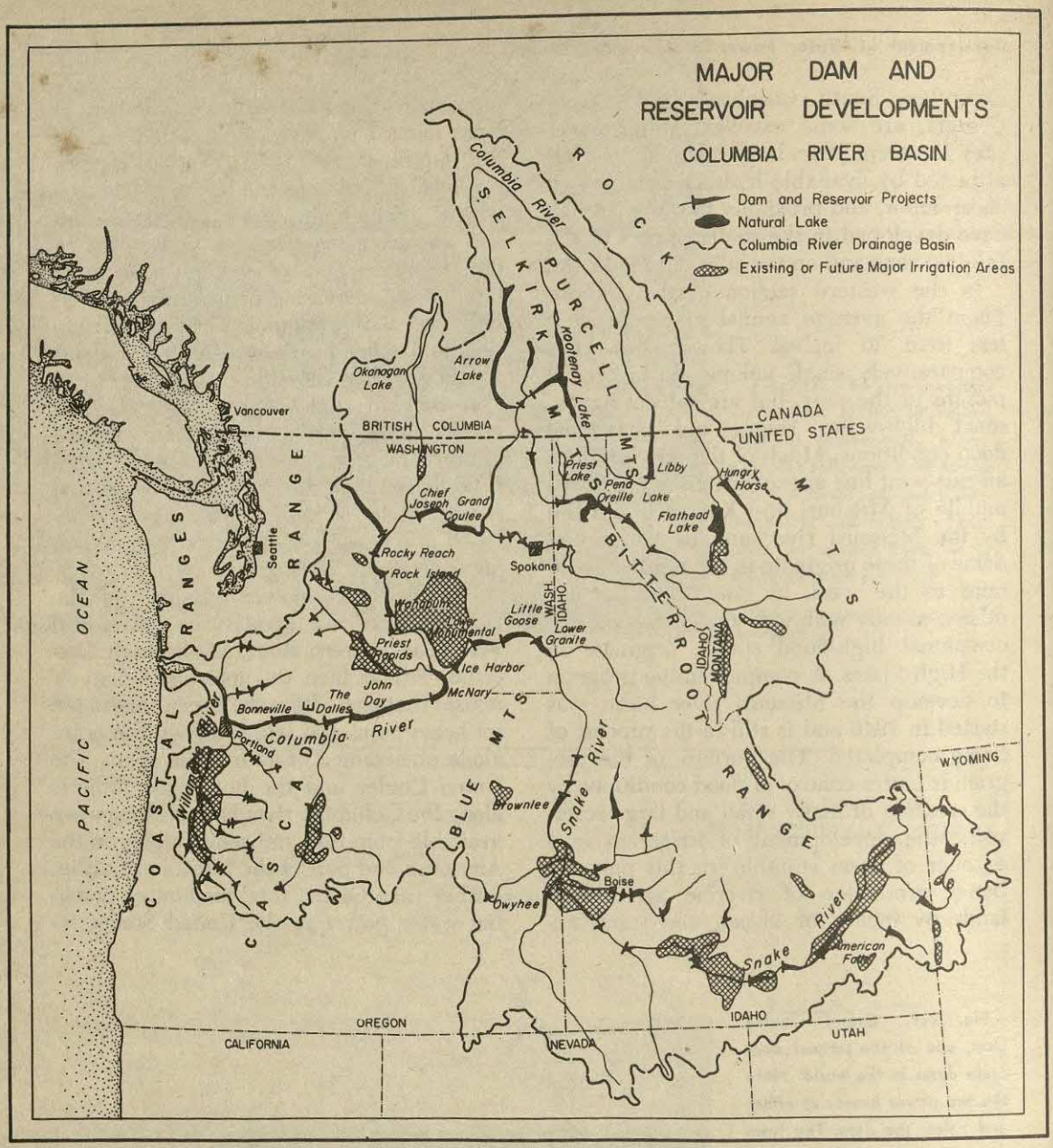


Figure 230.

cluding Alaska and Hawaii, about one fifth is in Washington and Oregon. The absence of extensive coal beds and oil deposits in this section of the country enhances the importance of the water-power resources (Figs. 229, 230).

In California the slopes of the Sierra Nevadas receive heavy precipitation, also partly in the form of heavy winter snows, from invading masses of Pacific air. Although the tributaries of the Sacramento and San Joaquin rivers are relatively small, their number and their swift descent give rise to comparatively great power potentials. As a result of the demands arising from the rapidly increasing population, the water-power resources of California are more fully utilized than are those of the other Pacific states. In California about 28 per cent of the available potential is in use,

whereas, for the Pacific coast states as a whole, only about one fifth of the potential has thus far been developed.

The Colorado river flows through one of the most arid sections of the country, but melting snows in the Rocky Mountains and the higher parts of the Colorado Plateau, furnish abundant water. In most of southwestern United States power development is incidental to the conservation of water for irrigation purposes, for example, at the Coolidge and Roosevelt dams, on two of the southern tributaries of the Colorado river. The Hoover Dam project on the Colorado river ranks as one of the largest irrigation and power projects in the world (Figs. 222 and 231). It is designed to equalize the flow of the lower Colorado river so as to prevent loss of water during times of flood, to furnish water to municipalities and for existing irrigation purposes throughout the year, to increase the area of irrigable land, and to produce cheap power for domestic and industrial purposes.

WATER-POWER DEVELOPMENT IN EUROPE

Italy, France, Switzerland, Germany, Norway, and Sweden produce about two thirds of the hydroelectric power developed in Europe west of Russia.

In Italy the absence of coal resources has served as an incentive for the development of water power. Part of the country is mountainous and receives considerable precipitation, especially the Alps and the northern Apennines. The principal water-power sites in Italy are found in the mountains around the densely populated and industrialized

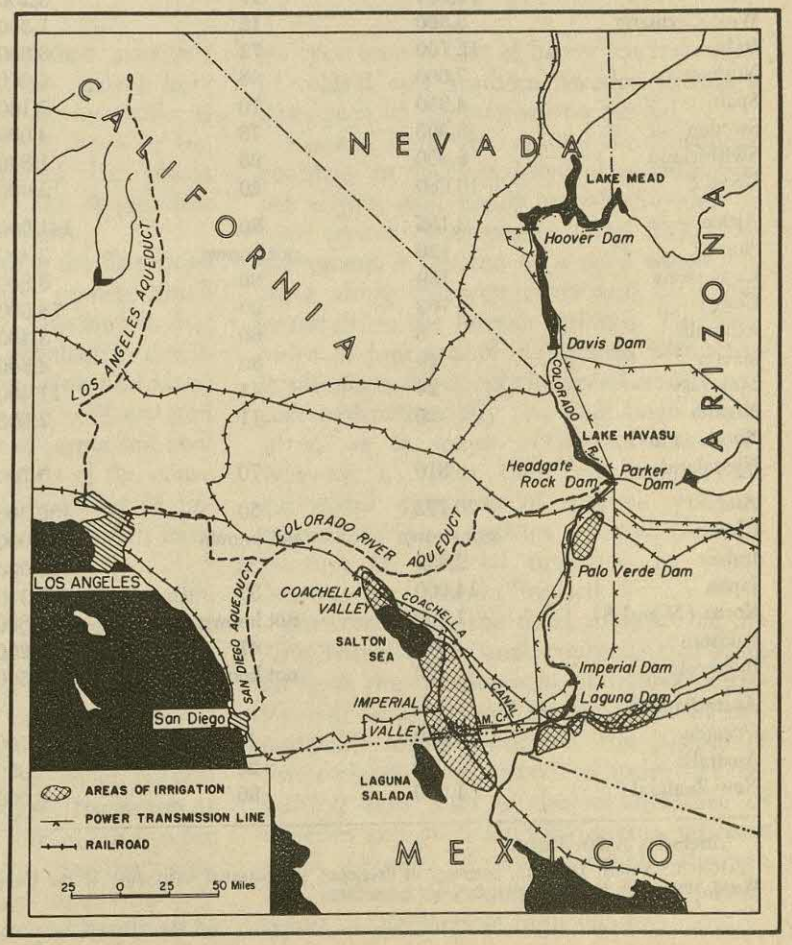


Fig. 231. Dams, lakes, and irrigated lands in the lower Colorado river basin.

CONTINENTS AND MAJOR COUNTRIES DEVELOPED AND POTENTIAL WATERPOWER IN MEGAWATTS (MW)
as of December 31, 1962

Continent and/or Country	Installed hydro-electric capacity in mw	Percent (approx.) waterpower installations of total electric generating installations	Estimated potential waterpower available 95% of the time at 80% efficiency	Estimated potential waterpower, arithmetical mean flow at 80% efficiency
North America, Central America and West Indies	61,230	24	72,052	216,000
United States	38,600	17	27,200	96,700
Canada	20,315	83	34,600	57,000
Mexico	1,900	44	5,100	27,000
South America	6,865	50	40,600	377,000
Brazil	3,850	80	12,000	144,000
Chile	688	52	7,600	21,300
Colombia	585	55	3,200	60,000
Europe *	85,800	40	43,750	167,600
Austria	3,600	75	2,600	5,600
France	10,900	47	3,200	9,600
West Germany	3,500	12	1,300	3,000
Italy	12,700	72	3,600	12,000
Norway	7,600	98	6,000	16,800
Spain	4,850	70	2,100	9,600
Sweden	8,300	78	4,000	18,000
Switzerland	6,400	96	1,800	5,600
USSR *	19,000	20	12,000	60,000
Africa	3,185	60	141,000	548,000
Angola	120	not known	3,400	63,000
Cameroons	159	90	3,800	23,000
Congo	763	90	78,000	144,000
Ethiopia	8	60	3,400	28,000
Gabon	19	60	4,800	17,500
Malagasy	24	44	11,400	64,000
Nigeria	20	11	7,600	17,600
Rhodesia and Nyasaland	810	70	3,700	18,000
Asia	20,192	50	136,200	816,600
China	not known	not known	32,000	176,000
India	2,450	33	25,000	69,000
Japan	14,000	53	7,200	15,000
Korea (N and S)	1,350	not known	1,800	3,000
Pakistan	346	41	5,250	12,000
Indonesia	200	not known	13,500	103,600
Australia and Oceania	3,660	40	7,700	53,400
Australia	2,000	25	600	22,800
New Zealand	1,550	80	3,000	6,600

* includes Asian Russia

SOURCE: Young, Lloyd L., Summary of developed and potential waterpower of the United States and other countries of the World, 1955-1962. U.S. Geological Survey Circular 483.

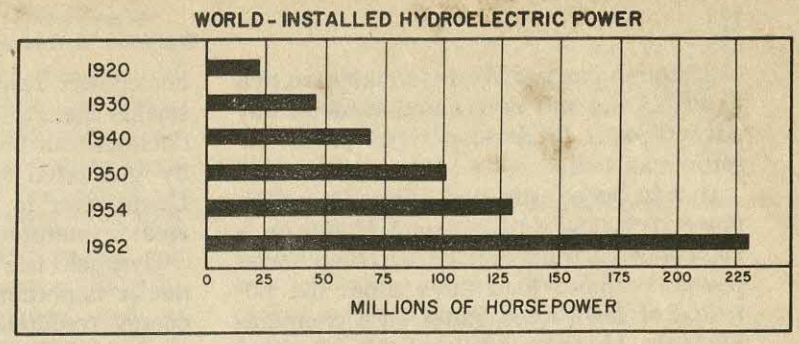


Figure 232.

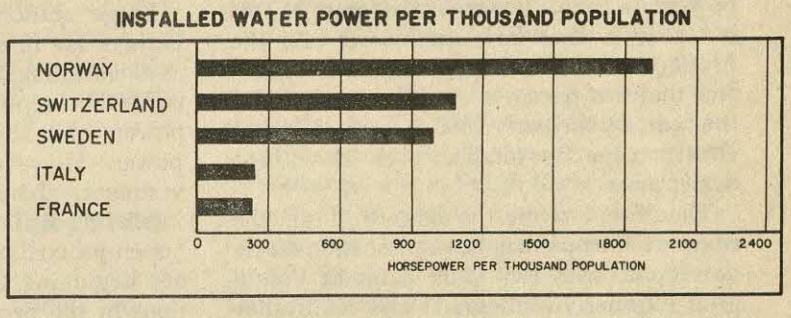


Figure 233.

Po Valley. This area is another excellent example of the fact that no matter how much hydroelectricity may be available, it is nearly always necessary to have in the system a number of thermoelectric plants as well, so as to make it possible to equalize the flow of generated electricity.

France ranks second among the European nations in developed water power. Small developments are widely distributed, but the principal areas of hydroelectric development are in the Alps, Pyrénées, and along the streams that head in the well-watered Central Plateau. The lack of important coal resources in the southern parts of the country and the widespread availability of potential water power are factors which have led to this regional development.

According to recent estimates, Sweden ranks third in Europe in developed water power, exceeding Norway by a small margin. Sweden is fortunate in having extensive potentialities which can be readily developed because many of her streams are interrupted by lakes which serve as natural reservoirs to regulate flowage. Inasmuch as power is needed for iron mining and paper mills in the north and for manufacturing farther south, markets for electric power are near at hand. The principal handicap to be overcome is that of heavy ice formation in central and northern Sweden during a large part of the long winter period.

Norway ranks first among the European countries in developed hydroelectric power per capita and nearly equals Sweden in total power development (Fig. 233). Development is favored by a mild winter climate along the west coast and by heavy snowfall on the interior uplands. This provides all-year run-off via streams with steep gradients to the deeply indented coast. Low-cost hydroelectricity has long been recognized as a major economic asset for Norway, a factor that has favored the successful operation of several types of manufacturing industries, such as the production of artificial nitrogen, in which Norway far outranks Sweden.

Switzerland is the third member of the "Big Three" of the small countries that loom large in the development of hydroelectricity. Not being favored by coal or bulky raw materials for manufacture, the people of Switzerland have turned to industries requiring skill such as the manufacture of watches and precision instruments, wherein small amounts of raw materials, through skill and use of readily controllable power, result in products of high value.

Although parts of West Germany are rich in coal, it has still been found economically advantageous to develop water-power resources as well.

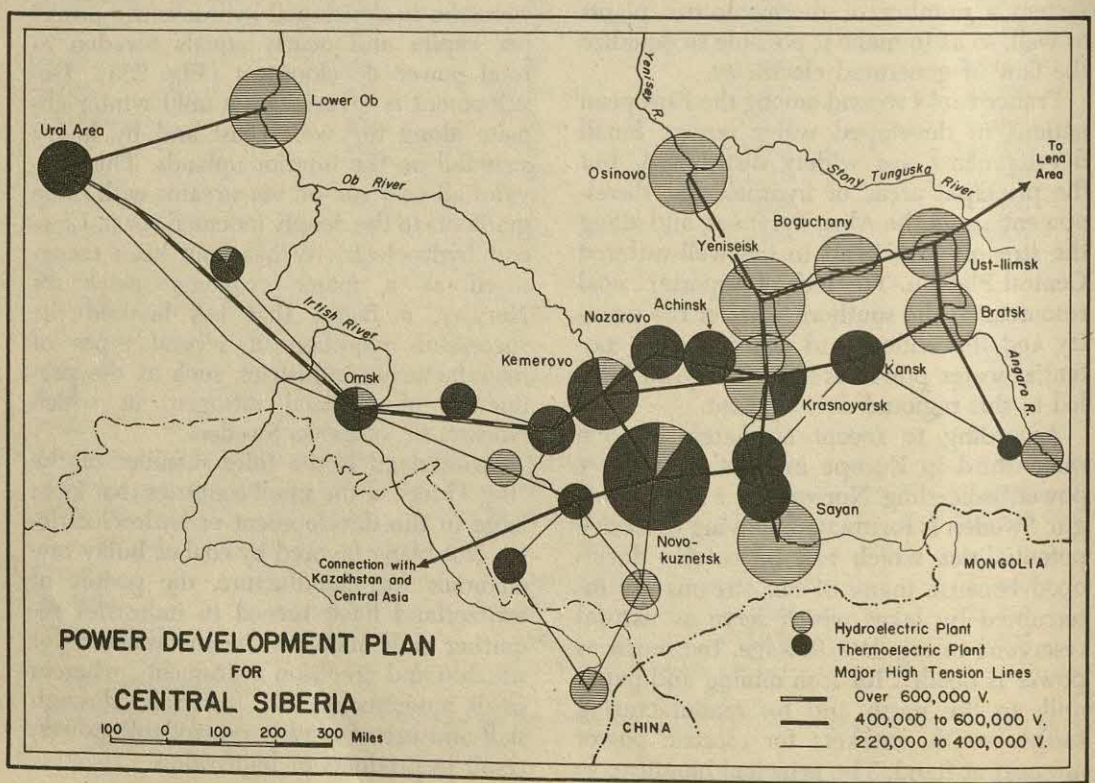
It has been estimated that the water-power potential of the Soviet Union on a mean flow basis may total 375 million horsepower, or more than three times the potential of the United States on a comparable basis. About four fifths of this is located in the Asiatic part of the country. It should be kept in mind, however, that part of this is on rivers that flow northward into the Arctic Ocean, that have a difficult regime, and that are frozen a considerable part of the year. By the early 1960's installed hydroelectric capacity totalled over 19 million horsepower.

The Volga river, the largest of all the rivers of Europe, has been most intensively developed, with two giant dams at Volgograd (formerly Stalingrad) and Kuibyshev with installations of 3.4 and 3.1 million horsepower respectively, and a number of smaller dams and installations together producing about two fifths of all hydroelectricity generated in the Soviet Union. The Dnepr river in the southwest is a second area of intensive development.

Hydroelectric development has had particular importance for areas poor in other energy resources, such as western Transcaucasia, Soviet central Asia, and the northwestern European part of the USSR.

Large stations have been built in Siberia or are in process of construction, such as Novosibirsk, 545,000 horsepower; Irkutsk, 950,000 horsepower; Bratsk, 6,100,000 horsepower; and Krasnoyarsk, 6,800,000 horsepower. However, the smaller initial investment, shorter construction time, and increasing availability of low-cost fossil fuels (open-pit coal, natural gas, and petroleum) are beginning to favor thermoelectric stations in the present scheme of Soviet economic development. In addition, the latter

Fig. 234. Note the combination of water-power developments and thermoelectric plants considered necessary for the production of an even flow of energy.



energy resources are better located with reference to existing domestic and industrial markets in the Soviet Union (Fig. 234).

As a continent, Europe is rather fortunate in the distribution of her power resources. The countries with little or no coal, such as Italy, Switzerland, Sweden, and Norway, are rich in water power, while the countries weak in water power, such as England, Poland, and Germany, are rich in coal. Russia has large reserves of coal and potentialities of water power, which is true also, although in lesser degree, of Spain, Austria, and Czechoslovakia. The Balkan states have considerable potentialities of water power, but are lacking in large-scale development.

OTHER REGIONS OF WATER-POWER DEVELOPMENT

Water power in Asia. As may readily be observed from the Table on page 352, Japan is far in the lead in Asia from the standpoint of developed hydroelectricity. Japan has installed water wheels and dynamos that will deliver electric current almost equal to the published potentials computed on the basis of minimum stream flow. The factors that have led to this high development include, of course, abundant precipitation, mountainous topography, and need for industrial power, to which must be added the zeal and energy of the Japanese people, a factor not to be overlooked.

Korea has made long strides forward in the development of water power in proportion to estimated potentialities. On the whole, however, one must recognize that hydroelectric development in Asia—for the continent as a whole—has made little progress in proportion to its potentialities.

Water power in Africa. As shown by the Table on page 352, Africa is the outstanding continent in potential water power, credited with about two fifths of the potential water power of the world. However, very little has been developed. Why such great potentials but so little development? In the first instance, part of Africa is in the low-latitude belt of heavy rainfall, and much of the continent is plateaulike with sharp descents to the sea, thus providing considerable heights of fall for large amounts of water. Second, markets for power have been small and scattered. The great power markets are industrial areas, of which, so far, the nearest are in Europe, separated from the potential African sites by all of arid northern Africa. Thus it seems probable that hydroelectric development in Africa on a scale commensurate with the huge potentialities must await or accompany the establishment of large industrial centers within the continent, or markets for hydroelectric power must be found outside the continent. Thus far any possibilities of the latter kind have been defeated by the transmission losses that would be involved.

Water power in South America. South America is in fourth place among the continents from the viewpoint of developed power, while on the basis of potentialities she is virtually on a par with Europe. Brazil has distinct leadership, being credited with about one third of the potential and nearly two thirds of the developed water power of the continent. In potential power, Brazil is followed by Chile, Colombia, and Peru in the order named, the same order holding true for developed power. The developed water power of South America is but a small percentage of the reported potential. Inasmuch as most of the known power sites necessitate construction of expensive dams, distant from large markets, the expansion of hydroelectric power will probably proceed slowly (Table p. 352).

Water power in Oceania. Oceania has developed only a comparably small percentage of her potential water power. In development per capita, New Zealand holds first place in Oceania by a large margin. Development here is favored by mountainous terrain, ample rainfall, and demand for industrial power springing from an energetic and fairly numerous population. Australia, with a much lower per capita development, is largely a continent of little rain, and in the eastern and northeastern sections where rain occurs and where water-power conditions appear most favorable, ample reserves of coal, easily mined, provide competition.

WATER POWER AND INDUSTRY

Water-power developments not only provide light and power for domestic purposes, but they usually sell a large percentage of their current to industry. With the aid of high-tension lines, electricity can be distributed over large areas. In recent decades the distance over which it is profitable to transmit electricity has been increasing gradually, and the networks of power lines are growing in size and increasing in density. Nevertheless, there are a number of industries which tend to congregate around power sites because of their large demands for cheap power. Among these should be mentioned particularly the electrochemical industries, such as the manufacture of nitrates and calcium carbide, and the electrometallurgical industries, of which the manufacture of aluminum from alumina and that of special alloys are typical examples.

The problem of long-distance transmission. At present it is possible for a large electric-power plant to transmit electricity economically over a distance of somewhere between 200 and 250 miles. At larger distances losses become too great for economic feasibility of transmission. This has always been a troublesome problem, as transmission over larger distances is frequently highly desirable. For example, Norway can produce much more hydroelectricity than it needs for its own consumption, and sales of surplus energy to Western Europe would be a distinct economic asset to the country. Russia has a similar problem: the area east of the Urals has a potential surplus which would be exceedingly useful in the European part of the country. The potential African surplus has been mentioned above.

Power that is generated at hydroelectric (and also at thermal) plants is in the form of alternating current, and in this form it is transmitted via high-tension lines. Voltage changes can be brought about by means of relatively inexpensive transformers. Unfortunately, losses along high-tension lines have limited the radius of distribution to the approximate range mentioned above. Direct current can be transmitted over longer distances and thus would be more efficient, provided that suitable and not too expensive machinery for converting alternating current to direct current and back again at large loads be available. It appears that such machinery now is beyond the experimental stage. Using this principle and newly developed equipment, a 300-mile transmission line has recently been put in operation in the Soviet Union, between Volgograd (the former Stalingrad on the Volga river) and the Donets Basin or Donbas to the west. If this new type of line is successful, the economic range of transmission may well increase to considerably over 300 miles.

Cost of water power. The fact that no fuel need be purchased by hydroelectric plants has led many people to believe that electricity can be produced and distributed by such plants almost free of charge, or at least much more cheaply than by coal-burning (thermoelectric) plants. This impression is erroneous and results from the fact that the public fails to take into consideration the huge expenditures necessary for the installation of great water-power plants. Furthermore, power sites often are found at considerable distances from industrial and marketing centers, thus involving costs of long-distance transmission. Inasmuch as all these factors must be taken into consideration in setting up hydroelectric establishments, the total cost of electricity generated may be found to equal or exceed the cost of that generated by steam plants. Still another factor not to be overlooked is that of gradual sedimentation of the reservoir and the resultant reduction of its capacity. Streams all carry varying amounts of sediment, which will settle to the bottom in the still waters impounded by a dam. The rate of filling will depend on the flowage of the stream, but since the best water-power streams generally are relatively swift owing to the high gradients, the load of sediment carried is usually comparatively heavy. Engineering safeguards may reduce the rate of filling and thus greatly prolong the life of reservoirs, but even so they involve added costs of maintenance, and rates

per kilowatt-hour must be computed accordingly.

The above is intended to aid readers to understand why hydroelectricity is not necessarily a low-cost form of power and to realize why dams and reservoirs should, wherever possible, be made to serve multiple functions, for example, irrigation, flood control, navigability, land use, and recreational resorts, as well as generation of electric power. Allocation of costs to the several functions served seems an equitable manner of procedure.

Fortunately, the present problem is not generally a question of hydroelectricity *or* steam-generated electricity. We need, and must have, both. As has been mentioned above, if *all* the possible water power in the United States should be fully developed, the amount of hydroelectricity would still fall far short of meeting the nation's power needs. Increasing efficiency of coal-fired steam engines is thus a factor of high industrial significance because low-cost power is essential to high production and general prosperity, so that homes and businesses in rural areas, as well as in the cities, will be able to obtain electric service at a cost that is within their economic reach. This is another goal ardently sought in this age of distributable power.

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21

Coal—A King Dethroned?

For untold thousands of years people kept warm around wood fires, which shed a cheerful heat but required constant care and replenishment. Only relatively late in history, probably in Greek and Roman times, did man discover a black rock, coal, which, though it did not ignite as easily as wood, once it caught fire burned longer and more evenly and yielded a vastly larger amount of heat. By the Middle Ages, particularly in regions where the black rock was available and where wood had become scarce, as in parts of England, the Low Countries, and Germany, coal was mined and sold in small quantities for heating purposes. In England there even developed a considerable coastal trade in coal from the Newcastle to the London region. Thus for a number of centuries coal was used for heating homes and in small industrial establishments such as blacksmith or other metal-working shops.

Demand for coal remained small until the invention of the steam engine. In some of the first steam engines the water was heated by wood, but it soon became evident that for steam engines of any size a much more concentrated fuel, coal, was needed. Thus the easy availability of coal in Great Britain made possible the Industrial Revolution. Steam engines began to utilize the enormous amounts of energy locked up in British coal fields, furnishing power for machines that became ever larger, and more and more complicated. The days of primitive machines, consisting largely of wooden parts and driven by animals or by small water wheels or windmills, were past.

However, the use of coal for space heating and later for the generation of energy comprises only part of the story. Investigations into the chemistry of coal tars—the residue left after coke and coal gas have been produced—made possible the manufacture of high-grade, low-cost dyes, a field in which German chemists won world-wide renown during the latter part of the last and early part of the present century. Thus coal became also a basic resource for the manufacture of a large variety of chemical products. These include not only dyes, but also drugs, perfumes, insecticides, fertili-

zers, fibers (some of silklike appearance and quality), and many other items.

GENERAL ECONOMIC POSITION OF COAL

Although changes may be impending due to the possibility of converting nuclear energy into mechanical power, coal will probably remain for a long time a major fuel and power resource for modern industry. The enormous expansion of coal mining during the past century has been due largely to the introduction into our factories of labor-saving machinery and mechanical devices for power utilization; it is also true, however, that such machinery could not have been manufactured or utilized if coal had not been available to provide heat and energy.

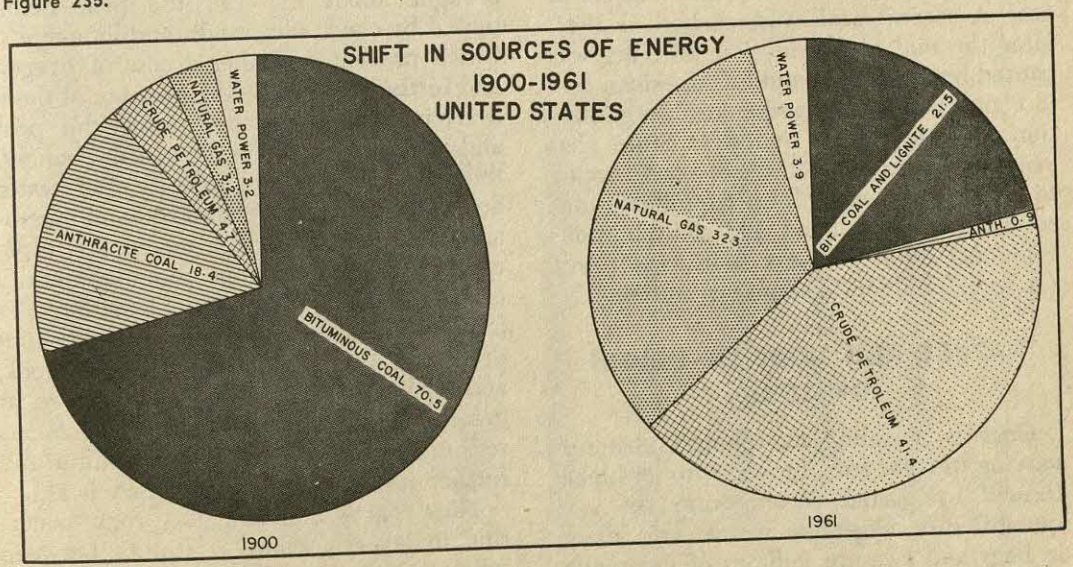
Generally speaking, the great industrial nations of the world are still the great coal-using nations. One needs merely to mention a few as illustrations: Great Britain, Germany, France, Russia, and the United States. The astounding material progress made by these nations has depended more upon coal than upon any other source of energy.

In the United States, so rich in oil and natural gas, coal has lost much of its former dominant position in the energy field. However, from a world point of view coal is still far from being a king dethroned. It is true that also in other countries where coal used to reign supreme, Great Britain and Germany, for example, the competition of oil is keenly felt. On the other hand, quite a number of countries without easy access to oil, or with insufficient oil resources, such as China and India, are still increasing their production of coal. Total world production of coal is still rising.

In the United States the value of the annual output still gives coal a rank among the leading commodities produced, and between one fourth and one fifth of all energy used in the country is still derived from coal. Coal has long been the greatest single item of railroad freight (Fig. 235).

Some mining of coal was carried on during the colonial period by individuals who found outcrops along valley sides and took out small quantities for local use. Coal mining as an industry, however, can hardly be said to have existed in the United States until after 1820. In 1821, the earliest year for which a record is available, the total output was only 1,322 tons. Production increased slowly, but more rapidly after the

Figure 235.



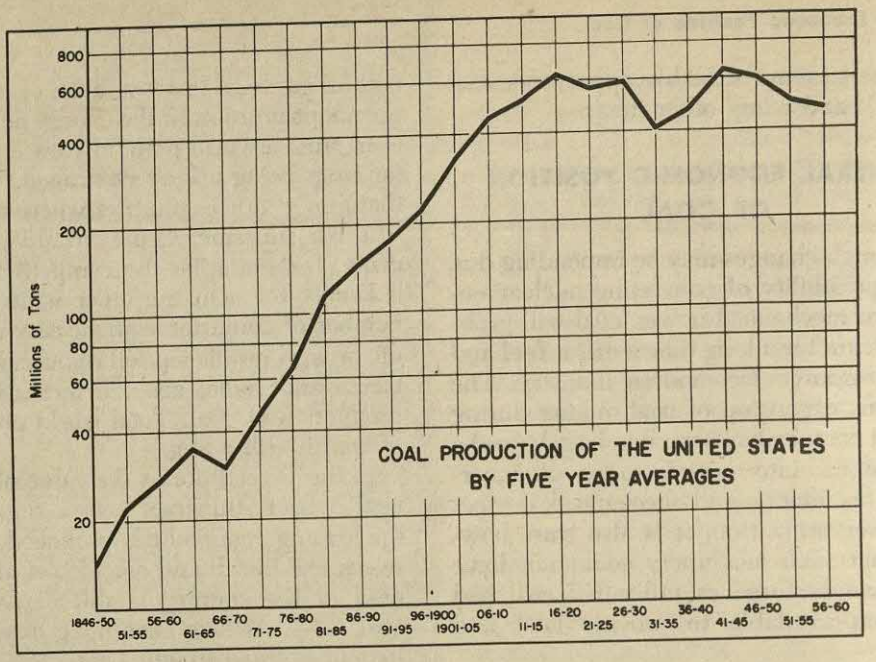


Figure 236.

middle of the nineteenth century, and from 1870 to 1910 each decade virtually doubled the output of the preceding one, a peak being reached during the period of World War I. Marked fluctuations have characterized the years since 1920, and because of the competition of petroleum and natural gas the general level of coal output has declined except for the World War II period, which again called for a heavy output of coal. A second peak was reached in 1947, after the end of World War II. This was caused by a high demand for American coal in countries that suffered from disorganization of their mining industry. Since that year production of anthracite has dropped to about one third (from 64 million tons to less than 20 million), and of bituminous coal and lignite to less than two thirds (from 620 million to about 400 million).

NATURE AND MODE OF ORIGIN OF COAL

Coal is a solid, amorphous substance varying in color from brownish to jet black, formed by partial decomposition of vast quantities of vegetable matter laid down in bogs and swamps millions of years ago. Between periods of swamp conditions and accumulation of vegetable matter there were other periods, when the water became deeper, and mud and sand were deposited, or even organic lime-mud, now hardened into shale, sandstone, or limestone. The processes of decay of the vegetable matter were slow and incomplete, as little oxygen could penetrate to it, and peat formation resulted. The change from peat to coal was brought about by: (1) the peat being buried by clays, silts, sands, and lime-muds, which prevented further access of oxygen and further decay; (2) the pressure of these overlying materials compacting the peat and furthering certain chemical changes, the latter causing the formation of water and gases such as carbon dioxide and methane—the escape of which meant loss especially of oxygen and thus an enrichment in carbon of the remaining plant matter; (3) final burial of the plant matter under hundreds and even thousands of feet of rock, accompanied by a rise in temperature at greater depth; and (4) earth movements resulting in folding of the rock strata and further increases of pressure and heat.

Thus coal is a sedimentary rock, occurring in layers (seams or strata) between other sedimentary rocks, such as shales, sandstones, and limestones. Coal can stand

only comparatively little metamorphism (high pressures and temperatures resulting from very intensive earth movements). Beyond a certain degree of metamorphism coal apparently disappears, but a small measure of it may improve coal to the ranks of semibituminous or even anthracite. In areas where rocks have been distinctly metamorphosed coal is not found, neither does it occur in igneous rocks.

THE IMPORTANT CONSTITUENTS OF COAL

Carbon is one of the principal products of the partial oxidation of woody matter. Since coal is of plant origin, carbon, so-called *fixed carbon*, is a major constituent. It is this element that imparts the black color and burns with little flame, high heat, and practically no smoke.

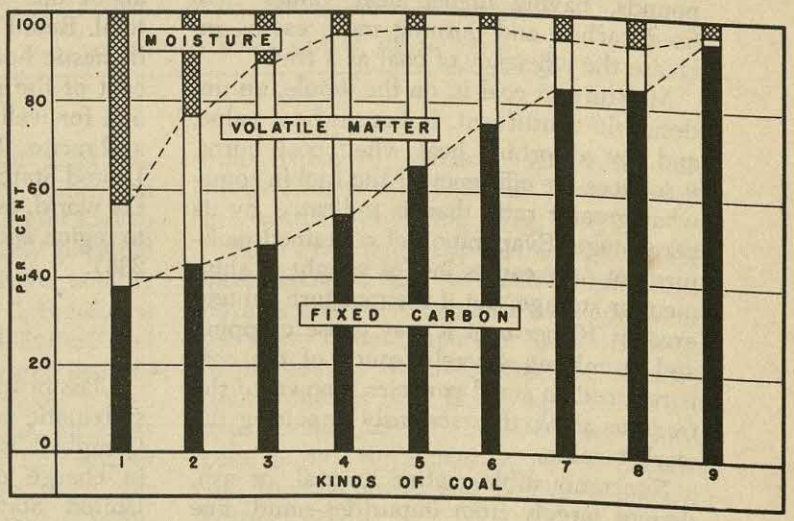
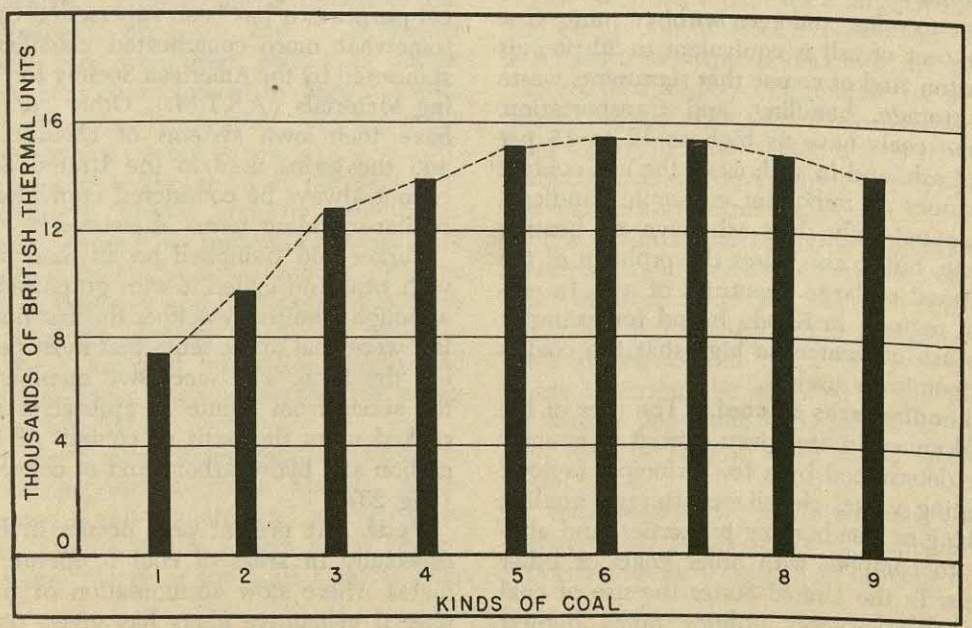


Fig. 237. Contents (above) and heating quality (below) of different kinds of coal. (After M. R. Campbell, Professional Paper 100, United States Geological Survey, Washington, D.C.)

1. Lignite
2. Sub-bituminous
3. Bituminous, low rank
4. Bituminous, medium rank
5. Bituminous, high rank
6. Semibituminous, low rank
7. Semibituminous, high rank
8. Semianthracite
9. Anthracite

One B.T.U. is the energy contained in one weight unit of fuel which raises the temperature of an equal weight of water by 1° F.



The other constituents of coal upon which its heat value depends are hydrocarbons, moisture, and ash. Coals with high percentages of fixed carbon and medium percentages of hydrocarbons have relatively great heat value, while those with high moisture content have low value (Fig. 237). The hydrocarbons consist of hydrogen and carbon, chemically united in varying proportions and various manners. These compounds, having higher heat values than fixed carbon and burning more easily, increase the efficiency of coal as a fuel.

Moisture in coal is, on the whole, an undesirable constituent. It has no heat value, and, by absorbing heat when coal burns, it reduces the efficiency of the fuel in somewhat greater ratio than is indicated by its percentage. Evaporation of contained moisture not only causes loss of weight in shipment or storage, but if the moisture content exceeds 10 per cent it may cause chipping and crumbling whereby much of the coal is reduced to small particles, known to the trade as *slack*, thus seriously impairing the market value.

Noncombustible matter in coal, or ash, derives largely from impurities—mud, fine sand, etc.—washed into the coal swamps at time of deposition. Thus ash content of coal may vary considerably in a region from mine to mine, and even within a mine. One per cent of ash is equivalent to 20 pounds per ton, and of course that represents waste in storage, handling, and transportation. Some coals have as high as 12 to 15 per cent ash, and in such cases the ash content becomes an important economic handicap, since not only does ash have no heating value, but it also raises the problem of the disposal of large quantities of ash. In certain regions, in Rhode Island for example, the ash content is so high that the coal is economically useless.

Leading uses of coal. The uses of the coal mined in any given district or country are determined by a few principal factors: heating value, cleanliness, storage quality, coking or free-burning properties, and ability to compete with other coals or other fuels. In the United States the use of coal for electric-power utilities ranks highest and accounts for about 45 per cent of the total output. About 20 per cent of the production is used in the manufacture of coke and by-products. In the recent past the railroads of the United States were not only major transporters of coal, as they still are, but also important users. However, since diesel and electric locomotives have replaced the steam locomotive, consumption of coal by the railroads has dropped to about one and one half per cent of the total. Retail deliveries, probably mostly for domestic heating, account for about 17 per cent of the production of bituminous coal, and for well over half of the production of anthracite. The data on use given for the United States do not hold for other parts of the world, as uses differ greatly from region to region and from country to country (Fig. 238).

KINDS OF COAL

Classification of American coals into a systematic series is credited to Parker and Campbell, who for a number of years were in charge of coal investigations for the United States Geological Survey. Their classification was widely accepted in the United States and is still useful for general economic purposes, although for technical purposes it has been superseded by the somewhat more complicated classification sponsored by the American Society for Testing Materials (A.S.T.M.). Other countries have their own systems of classification, and the terms used in the United States cannot always be considered equivalent to similar-sounding terms elsewhere.

Parker and Campbell began their series with peat and ended it with graphite coal, although admittedly neither the first nor the last were coal in the sense that most people use the term. The successive members of the series from lignite to anthracite were ranked upon the basis of content of fixed carbon and hydrocarbons and of coherence (Fig. 237).

Peat. At present peat occurs in bogs, especially in areas of cool temperate climates where slow accumulation of partly altered vegetative fibers has given rise to

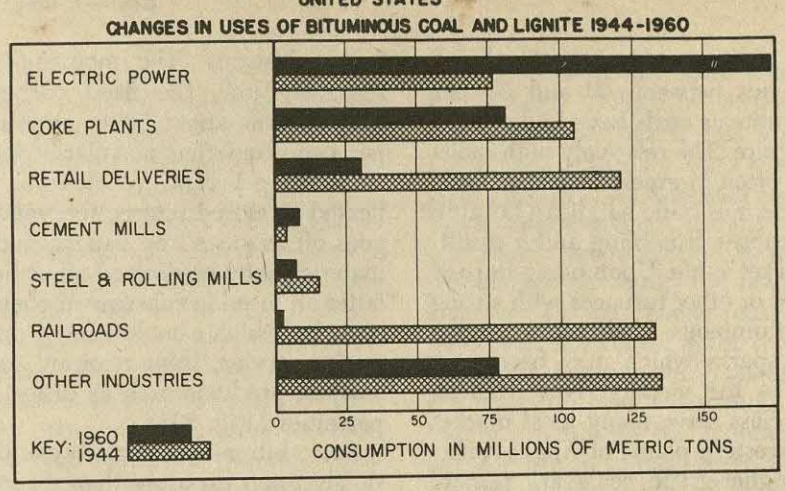


Figure 238.

deposits of varying extent and thickness. Its vegetative origin is clearly evident in the structure of the mass. The largest known deposits occur within the formerly glaciated areas of the Northern Hemisphere, notably in Ireland, Scandinavia, Finland, the Soviet Union, north central United States, and Canada. Peat is a bulky fuel which necessitates much storage space and involves high charges for shipment. Various attempts have been made to convert peat into smaller bulk through briquetting, but since this process adds materially to the cost, it is difficult for peat briquettes to compete with those made of fine coal.

Lignite. True lignite is brown or has a distinctly brownish cast. The higher grades vary from dark brown to almost black. It is characterized by high moisture content, generally about 40 per cent of the weight when freshly mined. The fixed carbon content is also about 40 per cent. The structure is fibrous and, in some cases, woody. Among the principal handicaps of lignite is its tendency to crumble into fine coal in shipment and in storage. While this fine coal has about as much heat value as the fresh lump, it burns less readily and therefore must often be marketed at a sacrifice (Fig. 237).

In the United States there are extensive lignite deposits in North Dakota, northwestern South Dakota, and eastern Montana. Lignite is also known to be present in many places in the Gulf Coastal Plain from Texas to Alabama. However, only North Dakota and Montana have production worth mentioning (Fig. 240).

Russia has large deposits of lignite. The most extensive ones are located in the Krasnoyarsk area of Siberia near the upper Yenisei river. Other important deposits occur in the central Ukraine, while the Moscow basin contains both lignite and subbituminous coals. Both of the latter fields have been highly developed in recent decades and furnish power and fuel to the neighboring areas.

In Europe extensive beds of lignite are found in the North German Lowland, where they are mined on a large scale for the generation of electric power and various industrial purposes, including the manufacture of a lignite coke suitable for use in blast furnaces. One of the most important uses for lignite, one worked out by the Germans, is that of converting it into synthetic petroleum and petroleum products.

The by-products of lignite liquefaction processes can furnish essential materials for the chemical industries. The ultimate possibilities of these processes have not yet been reached, and much progress along these lines may be expected in the future if natural petroleum becomes more expensive and, perhaps in some areas, unobtainable.

Subbituminous. Subbituminous coal is often called *black lignite* in trade circles. Its color varies from dull to lustrous black,

the structure is compact, and the fixed carbon content lies between 40 and 50 per cent. Subbituminous coals have higher heat value than lignite. The relatively high moisture content, often in excess of 20 per cent, constitutes a serious trade handicap because evaporation causes crumbling and a resultant lower market value. Upon being burned in locomotives or other furnaces with strong drafts, subbituminous coal often causes eruptions of sparks which may become a fire menace to the vicinity. Nevertheless, coals of this class serve many local market areas in the western plains of Anglo-America, where higher-grade coals are remote and therefore expensive (Fig. 237).

The best-known subbituminous coal region in the United States is found in the Great Plains in the so-called Sheridan District of northern Wyoming and adjacent Montana (Fig. 240). Production is small and has been declining. Coals of this kind occur also in the Denver basin and in a number of basins within the Rocky Mountain region. Because of the losses in weight and marketability which occur if the coal is kept long in storage, mining is largely seasonal, in autumn and winter.

It is unlikely that the near future will show any marked increase in the use of subbituminous coal in the United States. In the more distant future, when petroleum will not be as plentiful as it is now, the utilization of this coal may increase because its hydrocarbon content makes it suitable for the manufacture of artificial gas and liquid fuels. The enormous quantities of subbituminous coal known to exist in the Great Plains and the Rocky Mountains, the comparatively low cost of mining in many places if year-round operation can be maintained, and the low cost of transporting liquid fuels are factors which may some day lead to extensive exploitation for liquefaction purposes. Another possibility that should not be discounted is that the coal may be converted to gas at the mine and thus be made available for transportation by pipeline from mines to industrial consumers.

Bituminous. Bituminous coals are usually black, varying from dead black to highly lustrous. The moisture content is relatively low, the fixed carbon content ranges from about 50 to slightly over 80 per cent, and that of volatile matter from 40 to 15 per cent. When some types are heated in closed retorts, the volatile matter goes off as gases and vapors, and the tarry materials may be drained off as liquids. The latter are used in subsequent chemical processes by which a multitude of products are made, varying from semiraw materials to finished products such as drugs, dyes, and perfumes (Fig. 237).

Since bituminous coals break down more slowly upon exposure than do lower-grade coals, they may be kept in storage much longer. In the United States the principal producing districts are in the Appalachian Plateau, extending from western Pennsylvania and eastern Ohio to Alabama; in the interior plains of Indiana, Illinois, and western Kentucky; and in Iowa, Missouri, Kansas, and Oklahoma (Fig. 240).

The role of coke in industry. Coke is a product which is derived from bituminous coal and which has been essential in the smelting of iron ore. Due to the structure of coke it can withstand, without being crushed, the heavy weight of the alternating layers of iron ore in a blast furnace. In addition, the coke acts as a reducing agent, taking oxygen out of the ore and thus helping to liberate the iron. The combustion of the coke keeps the liberated iron fluid so that it can drain toward the bottom of the blast furnace, issuing from the furnace as so-called pig-iron. Coke has been made almost exclusively from highest-grade coals, just below the anthracites in rank, by burning or heating in retorts with an amount of air insufficient for complete combustion.

Earlier in the present century most of the coke in the United States was made in "beehive" ovens, where the gases that are formed during the process are wasted. At present 98 per cent of the coke in the United States is made in "slot-type" ovens or "by-product retorts," a method whereby all by-products, gases, and other chemical products are saved. Not all high-grade bituminous coals are suitable for the manufacture of coke. Usually two or more types of coal are

blended. If only one type is used, it is low-rank semibituminous. Even then it is not possible to predict cokeability: this has to be determined empirically. Reserves of this type of coal are small in the United States. Commonly a blend of high-rank semibituminous (15 to 30 per cent) and of high-rank bituminous is used. Thus high-rank semibituminous coal is now the critical item for coke manufacture. The largest reserves of this type of coal lie in West Virginia, Pennsylvania, and Arkansas, and *in toto* they constitute only about one per cent of total United States coal reserves. Suitable coals for coking are found in limited quantities in a few western areas, the Raton Mesa region of Colorado and New Mexico, the Sunnyside field of Utah, and the Somerset-Crested Butte-Carbondale region of Colorado. Coking coals have, of course, been in great demand for the smelting of iron ore, and areas where large quantities of suitable coals could be mined at low cost early attracted the iron and steel industry. In the United States, Pennsylvania is by far the leading state in coke manufacture, followed by Ohio, Indiana, Alabama, Michigan, and New York. Although at present the iron and steel industry is no longer bound as closely to coking coal as in the past, its geographic distribution in many parts of the world still reflects this early dependence.

In other areas of the world where coking coal is also scarce and expensive, certain bituminous types are mixed to achieve cokeability. A great step ahead has been the recent invention of a process—the Bilkenroth-Rammler process—which produces a very hard coke with a carbon content of 86 per cent from brown coal or lignite. This process is at present in operation in one of the lignite fields in East Germany, near the city of Kottbus, and will very likely be used in other parts of the world where coking coal is absent but lignite is available.

Dependence upon coke by the steel industry has been decreasing and will decrease further when new direct-reduction processes are perfected (see Chapter 24).

Semibituminous. Although the term semibituminous seems to imply that this grade of coal has half the rank of bituminous, it actually applies to a coal that is of higher rank. In the new A.S.T.M. classification this rather ambiguous term has been abandoned, and most coals of this type are now classified as low-volatile bituminous. The color is rich black, usually of high luster. The fixed carbon content is high, over 78 per cent; as a result, the coal burns with little smoke, and hence most semibituminous coals are known to the trade as *smokeless coals*. Because the moisture content is low and the heat value high, this coal is highly suitable for the generation of steam and for use in plants where high-temperature operations prevail. It is very important in the manufacture of coke, as discussed above (Fig. 237).

Semibituminous coals are found mostly in areas where the rocks have been folded, because there the coal has been subjected to greater pressure than where the layers lie nearly flat. In the United States this condition prevails in the eastern parts of the Appalachian field in Pennsylvania, Maryland, Virginia, and West Virginia and also in the southernmost portion of the Western Interior field in the states of Arkansas and Oklahoma (Fig. 240).

Semianthracite. Semianthracite coal differs from semibituminous in having a slightly higher ratio of fixed carbon, 83 to 93 per cent, and a somewhat lower percentage of volatile matter. It differs from true anthracite in being more friable, which causes greater likelihood of its breaking down into fine coal as a result of handling. The best-known mining districts are near Bernice, Pennsylvania, and along the flanks of the Ouachita Mountains in Arkansas and Oklahoma (Fig. 237).

Anthracite or hard coal. Anthracite is a hard and dense coal which is relatively free of iron compounds and moisture. The amount of fixed carbon may be as high as 95 per cent. It is jet black, lustrous, and of excellent coherence. The texture is fine, giving to the broken surface a smoothness which is almost a polish. It differs from semianthracite particularly in its hardness, a quality much desired because it permits preparation of sizes adapted to particular needs. Since there is virtually no loss in

storage and no danger of spontaneous combustion, it is well adapted for summer purchase by consumers. This is an important factor in facilitating steady, monthly output of anthracite in contrast with the sharp fluctuations of some bituminous mines.

Anthracite burns with a short blue flame and gives practically no smoke. The fire is remarkably persistent and can be regulated to give much or little heat as conditions may require. All of these properties make anthracite the most popular of the coal series for heating homes and larger buildings. The major deposits of anthracite in the United States are located in eastern Pennsylvania.

THE DISTRIBUTION OF COAL IN THE UNITED STATES

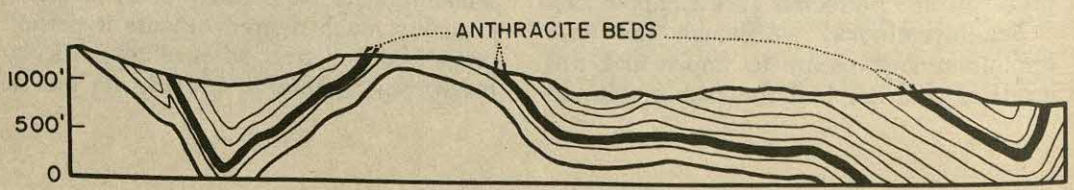
The coal fields of the United States are usually grouped into six major provinces: Eastern, Interior, Gulf Coast, Northern Great Plains, Rocky Mountain and Pacific Coast. Within each province there are from a few to many individual fields of greatly varying extent (Fig. 240).

The Eastern province. In output this province has always held commanding leadership in production of both anthracite and bituminous coal, and it contains four of the five states which lead in American coal output: Pennsylvania, West Virginia, Kentucky, and Ohio. Two coal regions can be recognized: the Pennsylvania anthracite region and the Appalachian bituminous field.

The Pennsylvania anthracite region is, for all practical purposes, the only area producing anthracite or so-called hard coal. Largest production is in Schuylkill and adjacent Luzerne counties, where the towns of Pottsville, Hazelton, and Wilkes Barre are located. Smaller amounts are mined in part of Northumberland County to the northwest of Pottsville and in Lackawanna County, the Scranton area. The structural conditions under which anthracite is found differ sharply from those that are prevalent in many bituminous areas (Fig. 239). The beds are usually folded rather sharply and broken in places, a condition quite different from the flat-lying or gently inclined continuous beds characteristic of American bituminous regions. The folding is the result of tremendous lateral pressures which are responsible also for the metamorphosis of bituminous coal into anthracite. While this change has produced a fuel of high quality and desirability, the folding has caused difficult mining conditions. The steep slopes in the mines and, in some places, the disturbed arrangement of the strata, together with the prevalence of thinner beds, all add up to lower output per man and necessarily higher cost of production per ton. For example, in the underground bituminous-coal mines of the United States the average production per man-day was 11 tons in 1960. This high production was due to two principal factors: (1) the near-horizontal position of the coal beds, their continuity, and accessibility; and (2) the widespread mechanization of the mines. In the anthracite fields the tilted and discontinuous beds are less favorable for mechanized mining and the output per man-day is only about half. The low production per man-day is largely responsible for the high price of anthracite compared with bituminous coal. Strip mining has increased greatly in recent years, to over one third of total production, but seems to have had little effect on prices.

For steam purposes, anthracite is generally unable to compete with bituminous, but for space heating its economic disadvantage is overcome by its persistent, clean-burning, and easily regulated heat. However, an ap-

Fig. 239. The flexed structure of the anthracite fields, a condition that gives rise to mining difficulties and necessarily greater expense of production per ton.

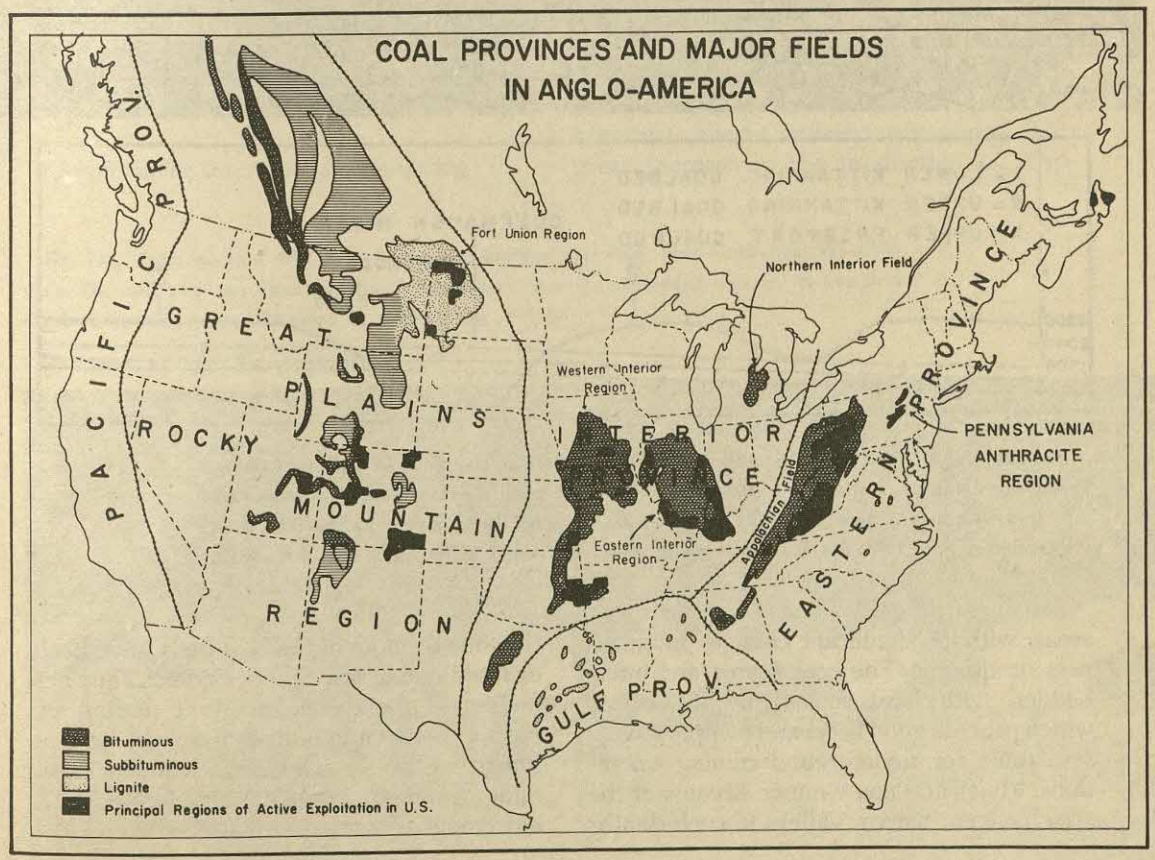


preciable amount is still used for generating electricity. Production of anthracite in the United States has decreased from a high of almost 100 million tons in 1917 to about 20 million in recent years. Of the total amount mined about one tenth is exported, mostly to Canada. The bulk is consumed in Pennsylvania, New York, and New Jersey. Some goes by rail and water to the Great Lakes states and by rail to New England. Employment in anthracite mining dropped from a high of 180,000 men, working an average of 245 days per year in 1914, to 19,000 working 176 days per year in 1960. Thus the anthracite region has become an area of chronic unemployment, with all of the attendant problems. The region is trying hard to attract various industries to compensate for the losses in employment in the anthracite fields.

The Eastern province owes its economic supremacy, however, to the extent of the Appalachian bituminous field and the high quality and accessibility of the coal deposits there. From an industrial point of view, this field has been aptly termed the greatest in the world. It extends from northwestern Pennsylvania southward throughout the Appalachian Plateau into northern Alabama. The coal has high heat value and keeps well in storage. In addition, some of it is of unexcelled coking quality. The mining districts of this region furnish fuel for industry throughout the eastern United States, and the coal has great importance also in gas making, in the generation of electric power, and for heating purposes.

Structural conditions within the Appalachian bituminous field are very favorable for low-cost mining. The beds, sometimes referred to as *seams,* are flat-lying or gently inclined and continuous over relatively large

Figure 240.



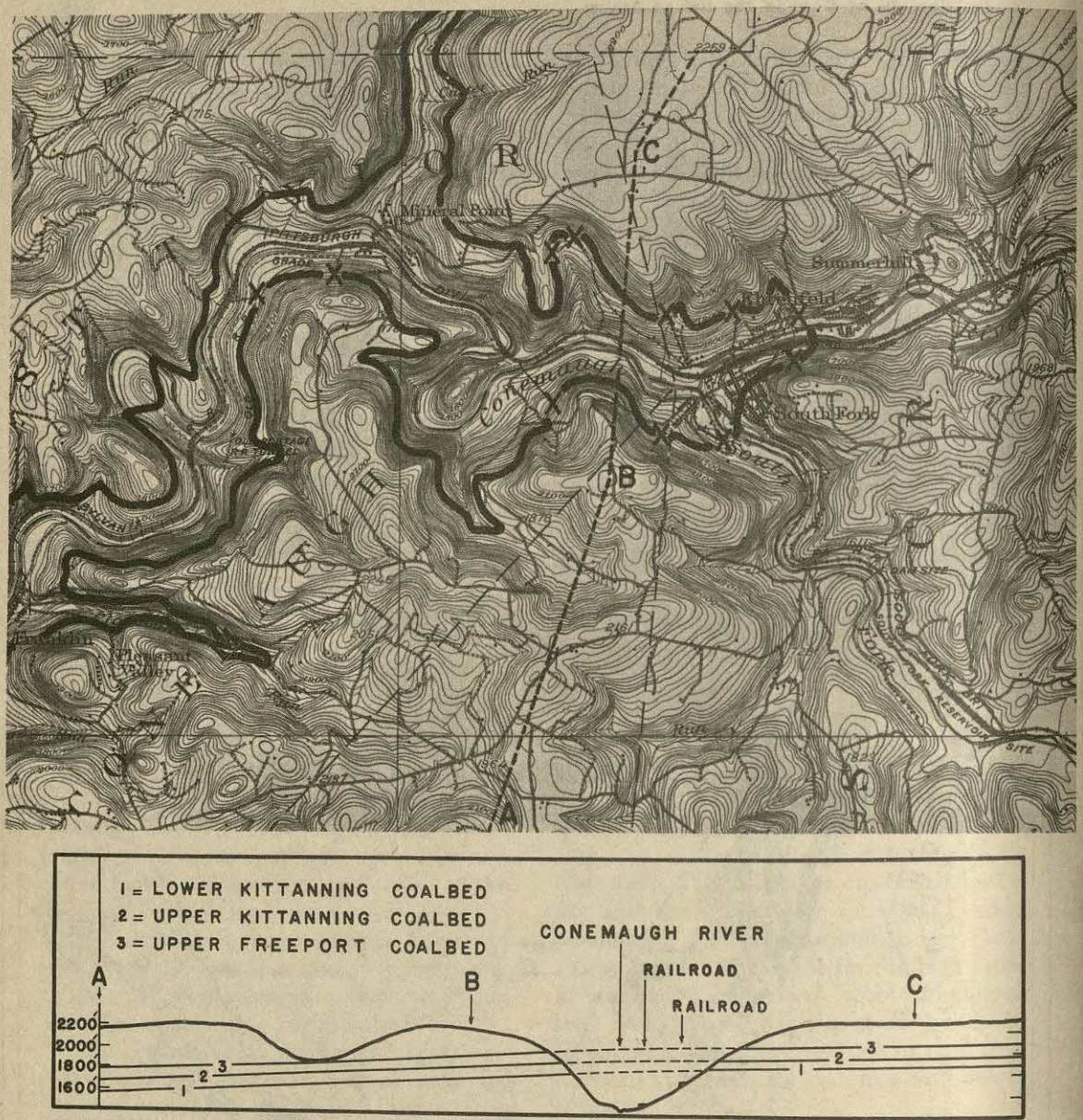


Fig. 241. Topographic map of a small part of the Appalachian coal field, in Cambria County, Pennsylvania. Outcrops of the principal coal bed are shown by a heavy black line. Mines are indicated by crosses. The map is not up to date as it has not been revised by the U.S. Geological Survey since 1904. The diagram below shows a cross section along line A-B-C of the map.

areas, without significant changes in thickness or quality. The coal seams are interbedded with hard shales and limestones which provide good floors and comparatively safe roofs for underground mining operations. Major and many minor streams of the area have cut narrow valleys to such depths that one or more of the coal beds have been exposed along the valley sides. This has facilitated the development of mining by means of drifts and tunnels above the level of the ground water and has made problems of mine drainage comparatively simple. Also, movement of coal out of the mines to the

railways built along the valleys is quite easy (Figs. 241 and 242). These conditions, coupled with available market demands, have favored the huge investments which are necessary for safe and efficient production. As a result, the mines in operation in the Appalachian field are now largely mechanized, which makes possible a high output per man-hour, with increased safety and higher income per capita. The significance of these favorable mining conditions is clearly demonstrated by the fact that in 1960 the average coal production per man-day in all underground bituminous-coal mines of the United States was about 10 tons, whereas in the United Kingdom, France, West Germany, Poland, the Netherlands, and the USSR production per man-day ranged between 1.7 and 2.0 tons. In many of the European fields the natural conditions are such that the output per man-day, even with all the mechanization that can be used advantageously, cannot equal that of the American fields. Their coal seams are too much faulted and tilted.

A remarkable development during the past decades has been the growth of strip-mining.[1] In this method the overburden of rock, clay, and shale is removed by huge tractor-propelled, diesel-powered and electric shovels and draglines, whereupon the coal is mined by open-cut methods, making unnecessary the expensive tunnels, shafts, and timbering that must be used for underground mining. The average cost of strip coal at the cut is about one third lower than that of coal from underground mines. Besides, production per man-day is more than twice as high, namely about 23 tons. No wonder that with the enormous pressure exerted upon the American coal industry by competitive fuels—fuel oil, gasoline, and natural gas—there has been a phenomenal increase in strip-mining. In 1930 out of a total of 468 million tons of bituminous coal and lignite produced, 20 million tons were strip-mined. In 1960 out of a 415 million-ton total, 123 million were strip-mined. Among the important coal-producing states, strip-mining accounts for about seven tenths of production in Ohio and Indiana and for nearly half in Illinois. On the other hand, in Pennsylvania less than one third is produced in this manner, and in West Virginia and Virginia less than one tenth. In Iowa, Kansas, Missouri, Oklahoma, and Wyoming the percentage of production that is strip-mined lies between 80 and 100 per cent. Lignite is almost entirely strip-mined. This great increase in the production of strip-

[1] Auger mining is a variant of strip-mining.

Fig. 242. Entrance to a drift mine, in the Appalachian coal field, near Cannelton, West Virginia. The coal bed runs nearly level with the hillside. A string of loaded cars on its way to a nearby preparation plant for cleaning, crushing and sorting.

Courtesy National Coal Association, Washington, D.C.

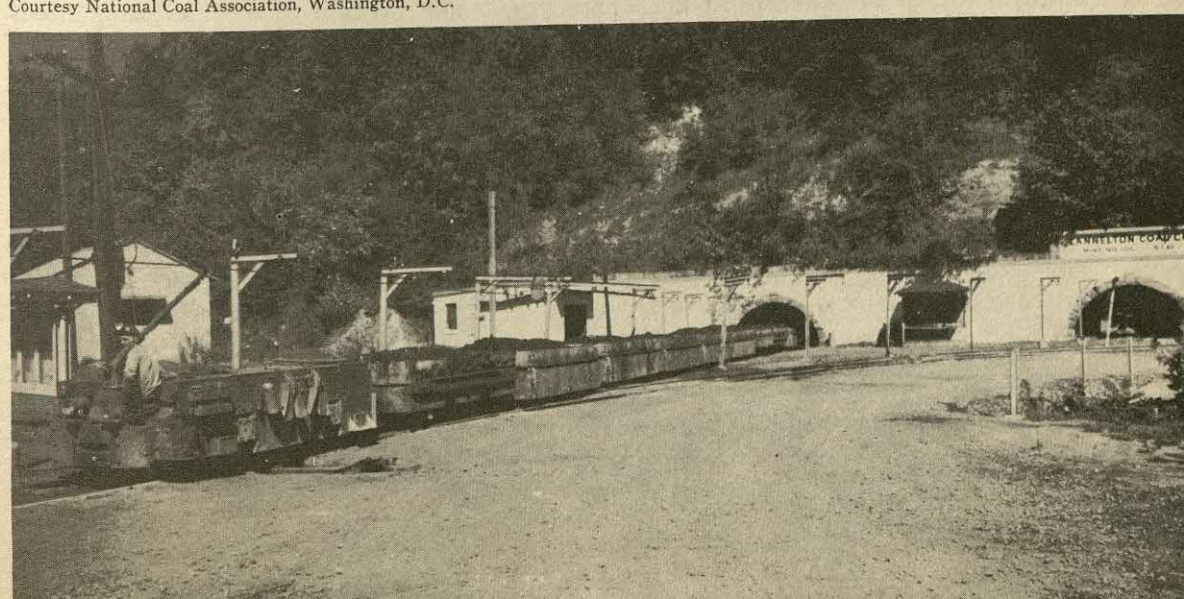




Fig. 243. Flat stripping of coal near Cuba, Illinois. Machine in middle ground removes overburden, at left, and piles it up to right, at the rate of 3,500 tons per hour. The two arms span 420 feet. Power shovel in background removes the last of the overburden to expose coal bed. Smaller shovels, not visible here, load trucks, such as the one in foreground.

Courtesy National Coal Association, Washington, D.C. and the United Electric Coal Companies

mined coal has been made possible by the development of very powerful machinery that has been capable of stripping off greater and greater thicknesses of overburden, some machines being able to handle over 70 feet. Nevertheless, there is an upper economic limit to this method, and in many fields there is a limit to the amount of coal that can be so produced. Where the amount of overburden is comparatively thin and even, considerable areas can be stripped advantageously. However, where coal seams crop out in valleys, and where thickness of overburden increases rapidly away from the valleys, coal can be stripped only "on the contour." The width of the area so stripped depends on the rate at which the overburden increases in thickness at right angles to the valley and the capacity of the equipment used (Figs. 243, 244).

Stripping leaves ugly wounds in the landscape, and several states have passed legislation which makes it mandatory for operators to do something about the highly undesirable consequences of this method of mining.

A factor of considerable importance to the coal industry east of the Mississippi river is the Great Lakes Waterway, which provides a cheap route for bulk cargo to markets of northern United States and adjacent parts of Canada where local supplies are wanting. Coals from the Appalachian field and even from the Eastern Interior field can thus reach northern markets. Over one tenth of the coal produced each year travels on the Great Lakes.

The bituminous coals of the Eastern province have for decades served highly important purposes throughout the section of the United States that has achieved the greatest industrial development. The American smelting industry, particularly the iron and steel industry, has been dependent to a large extent upon the high-grade coke from this region. In addition, it has been possible for the manufacturing industries to be supplied with steam coals at minimum rates. Although this area has in recent years experienced strong competition from petroleum and natural gas now available from distant sources, the demand for coal will continue because of the increasing needs for energy. Furthermore, although the reserves of oil and gas may be sufficient to supply eastern United States for some decades, from a long-term point of view the continuation of such a supply is questionable. The reserves of coal are so great that we may safely consider them to be available for centuries to come, whereas such cannot be said of natural gas and petroleum.

The Interior province. The Interior province includes four coal fields: (1) the Eastern Interior field of Indiana, Illinois, and western Kentucky; (2) the Western Interior field, embracing the coal-producing areas of Iowa, Missouri, Kansas, Oklahoma,

and Arkansas; (3) the Northern Interior field of Michigan; and (4) the Southwestern Interior field of Texas. The first two have attained considerable commercial importance, but the last two are of no importance at present. The Southwestern Interior field has hardly been touched. The coal in Michigan has a high sulfur content and occurs in isolated seams that are generally thin and pinch out in short distances. Although a total of about 50 million tons has been mined, there is no activity in this field now (Fig. 240).

The coals of the *Eastern Interior field* owe their economic importance chiefly to the demands of industry. However, in addition to these demands, the comparative density of population and the severity of the weather during the winter months give rise to a market for coal for space heating purposes. The Indiana, Illinois, and western Kentucky coals find markets largely within and adjacent to these states. Throughout this area the coal lies in nearly horizontal beds that are within easy reach for comparatively shallow underground mining and extensive strip-mining. Illinois, which is particularly fortunate in the extensiveness of its coal resources, in the low cost of its mining operations, the high quality of its coal, and its easy access to important markets—particularly those of the Chicago and St. Louis industrial areas—has become one of the four states leading in coal output.

The coal of the *Western Interior field* is characterized by high heat value and by a range in quality from bituminous to anthracite. On the flanks of the Ouachita Mountains of Arkansas and Oklahoma, folding has caused metamorphism of the coal into the high-fixed carbon group. Most of the reserves of these two states consist of high-rank semibituminous coal. In addition, Arkansas has semianthracite, and Oklahoma has low-rank semibituminous and high-rank bituminous coals. Of the two states Oklahoma is by far the larger producer. Elsewhere in the Western Interior field only the bituminous coals are found. However, they have high heat value, some of them ranking with the hottest coals found in the United States, and their low cost at the mine makes them excellent for industrial uses and for electric power. Missouri is the leading producer of bituminous coal, followed at some distance by Iowa and Kansas. In the entire Western Interior field strip mines are only somewhat more numerous than underground mines, but their production is between four and five times as large. Although in many sections of this field conditions are favorable for low-cost stripping, production is declining in all the states concerned, from a maximum of about 30 million tons during

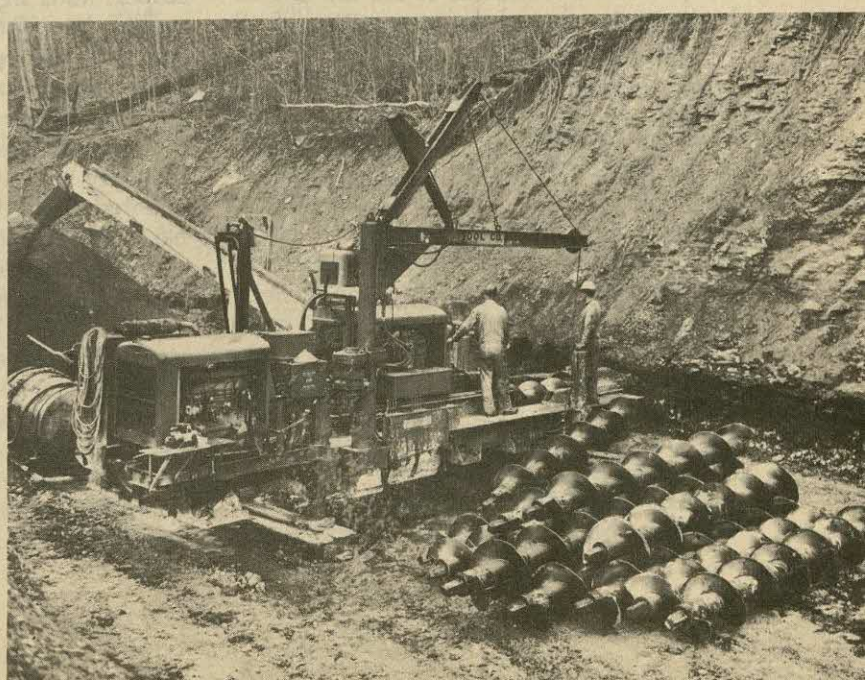


Fig. 244. When overburden above a coal bed becomes too thick for economic recovery by strip-mining, it is possible to drill into the bed sideways with giant augers up to about 200 feet. Note the coal bed to the right. The extra augers can be added to the one that is in process of drilling. The coal is piled up to the left. This method is particularly useful in areas of contour stripping.

Courtesy National Coal Association, Washington, D.C. and Salem Tool Co.

the years of World War I to about 6 million tons in 1960. The entire field is located in an area of intensive competition with oil and natural gas.

The Gulf Coast province. The Gulf Coast province extends from Texas to Alabama (Fig. 240). Only lignite has been found there. The poor quality, difficult mining conditions, and competition with oil and gas have prevented any extensive exploitation to date. It may be considered as a reserve for the future.

The Northern Great Plains and Rocky Mountain provinces. The Northern Great Plains and Rocky Mountain provinces contain enormous reserves of unmined coal, varying from lignite to high-quality bituminous, with a few places where coal of anthracite quality has been found. Exploitation in the past was chiefly for railway use, for smelters, and for domestic heating. Local mines have long been highly important to the communities that they serve and to the railroads that traverse the regions. The mining and smelting industries of the Rocky Mountain districts have been able to operate at relatively low cost because of the coal available from nearby sources. Production has been small in comparison with that of the eastern fields, because of the sparseness of the population in the vast territory included within these provinces and the distances to outside markets. Due to the almost complete discontinuation of the use of coal by the railroads and the competition of oil and gas, coal production has declined from a high of about 40 million tons to about 12 million. As has been mentioned, coking coals are available in Utah, Colorado, and in the Raton Mesa field on the border of New Mexico and Colorado. Commercial exploitation is not likely to increase in this area as long as cheap petroleum and natural gas are easily available for general industrial purposes. However, the great reserves of coal known to exist in the northern Great Plains and the basins of the Rocky Mountain region give assurance that the country need have no fear of a fuel famine for centuries to come (Fig. 240).

The Pacific Coast province. The Pacific Coast province includes a few insignificant areas in California and the coal fields of Washington and Oregon. The fields are small and, though there is some bituminous coal in both states and even some anthracite in Washington, they contain mostly subbituminous coal. Exploitation must meet the competition of oil from California and Canada, which is available at low shipping rates, and also of hydroelectricity, which has been well developed in this area. Domestic demands are light because of the mild winters characteristic of the Pacific Northwest. The only coal production of any significance is in Washington, and here it has declined from a maximum of 4 million tons in 1918 to about one fifth of a million at present. However, if a power shortage should develop as a result of further industrial growth, coal appears to be the logical source for increasing the quantity of power needed.

The geographical significance of coal distribution in the United States. In the Western Hemisphere the United States is unique for its large coal reserves in the interior, which are readily available for exploitation. Among the various economic effects of the distribution of the coal fields, three outstanding ones deserve emphasis. First, the coal fields of the eastern United States are more than 200 miles from tidewater ports. Railway transportation across rugged, mountainous country from mine to seaport adds significantly to the cost of the coal at the seaboard. This factor is a handicap to the development of a large export trade because of the competition of European coals mined near tidewater or navigable streams where the land transportation costs are slight. On the other hand, this is counterbalanced to a certain extent by the ease, and, therefore, comparatively low cost of exploitation of the Appalachian bituminous field. Second, the wide distribution of coal in the interior furnished, before the arrival of the diesel locomotive, the power necessary for a far-flung and intricate network of railroads and for industrial and agricultural development such as no other continent has ever experienced. The transcontinental railroad systems were provided by nature with natural refueling stations of

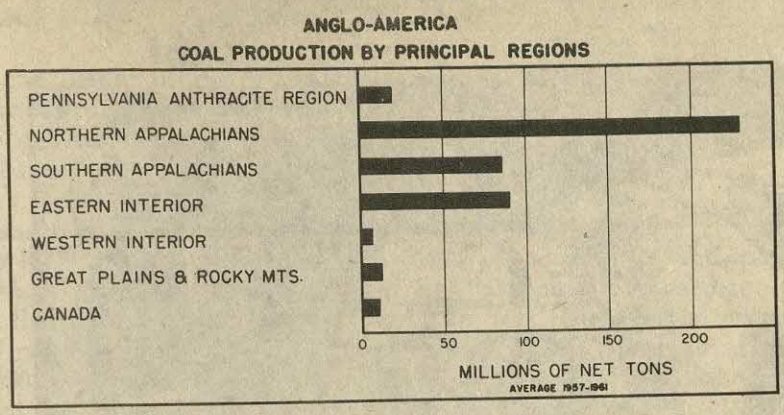


Figure 245.

coal available at relatively convenient intervals throughout their routes. Third, had there been coal along the coasts but not in the interior, the costs of hauling agricultural products to eastern industrial centers or to seaboard markets in pre-diesel days would have been much higher, in some cases prohibitive, and agricultural prosperity within the interior of the continent could not have been achieved. Without agricultural prosperity, industrial growth in the interior would have been impossible. Without the great markets of the Middle West and the Rockies, the industrial progress of the East would have been seriously curtailed. While other factors are, of course, involved, the coal fields of the interior from Pennsylvania to Colorado and Utah deserve much credit for the industrial development of the United States.

COAL PRODUCTION IN THE UNITED STATES

The annual production of all coal in the United States since 1950 has averaged slightly less than 500 million tons, but in recent years this has been much closer to 400 than to 500 million tons (see Fig. 236). Pennsylvania anthracite accounts for about six per cent of the total production. In the output of bituminous coal, West Virginia continues to hold commanding lead, followed by Pennsylvania, Kentucky, Illinois, Ohio, and Virginia. The importance of coal to the development of centers of heavy industry such as Pittsburgh, Cleveland, Detroit, and Chicago is evident (Fig. 240).

United States foreign trade in coal. Exports of American coal during the period preceding World War II constituted but a small fraction of the total output, usually between two and six per cent. Canada was then the foremost export market, taking nearly all of the anthracite exports and from 85 to 90 per cent of the bituminous exports. The importation of coal from the United States is favored by the proximity of the American coal fields to the most densely populated part of Canada, the area between Windsor and the city of Quebec, and by the remoteness of Canadian coal reserves, located mostly in the western plains country, in the basins of the western mountains, and far to the east in the Maritime Provinces, particularly in Nova Scotia. However, in recent years, also in the part of Canada mentioned above, there has been growing competition with gas and oil (Fig. 240).

The Caribbean lands buy some American coal, but their needs are small. Because of the intimate trade relations that exist between Brazil and the United States, that country is ordinarily a good market for American coal, the United States being the greatest customer for Brazil's foremost export, coffee. Argentina, although its exports of grains, meats, and other agricultural products go largely to Europe, in recent years has taken appreciable quantities of American coal.

During the period prior to World War II, American exports to European markets were small because European coals are mined near the seaboard or where water routes are available from the interior. As

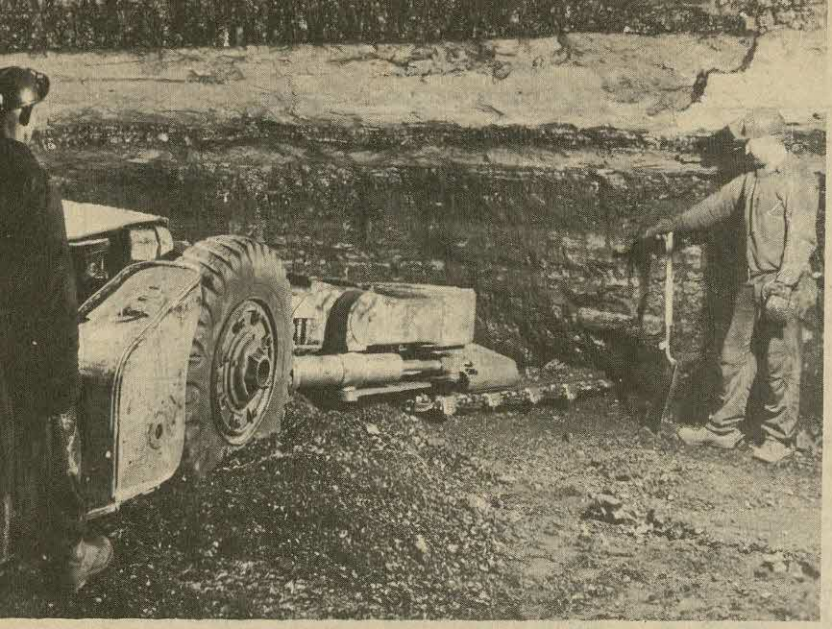


Fig. 246. Cutting under a coal bed preparatory to taking the coal out. Drift mine in Appalachian coal field.

Courtesy National Coal Association, Washington, D.C.

coal is bulky in proportion to value, low-cost water transportation from mine to market is a decided advantage for trade.

The export trade in American coal expanded greatly, particularly with European countries, during the war period and the years immediately following. During the five-year war period 1940-44, the American exports of bituminous coal were more than double those of the prewar period. During the postwar period the increase continued for a while so that by 1947 the tonnage had increased sixfold over the prewar period, making up 11 per cent of the expanded production of 620 million tons of bituminous coal and an equal percentage of anthracite production. Europe took more than 53 per cent of the total exports in 1947, compared with less than one half of one per cent during the 1935-39 period.

The reason for this great increase was that, because of the war, there was a complete disorganization of coal mining in important centers in Western Europe and a decrease in production even in Great Britain. These conditions were, however, only temporary, and with the restoration of coal production in Western Europe and Great Britain the exports of American coal to this area were bound to decline again. After 1947 coal exports to Europe showed great fluctuations, with other peaks occurring in 1951 and 1957. The 1957 exports to Europe reached a maximum that had never occurred before, almost 50 million tons, but they dropped to 17 million in 1960. On the whole, the competitive position of American coals in Europe has been stronger than it was after World War I, mostly due to an increase in production per man-day. This, as discussed elsewhere in this chapter, has come about through further mechanization of coal cutting, through a great increase in mechanical loading underground, and a phenomenal increase in the cheapest form of production, strip-mining. Nevertheless, the widespread use of petroleum fuels for bunkering and industrial purposes and the stronger competition from other coal producers, including the USSR, will tend to limit demand for American coals in Europe and elsewhere.

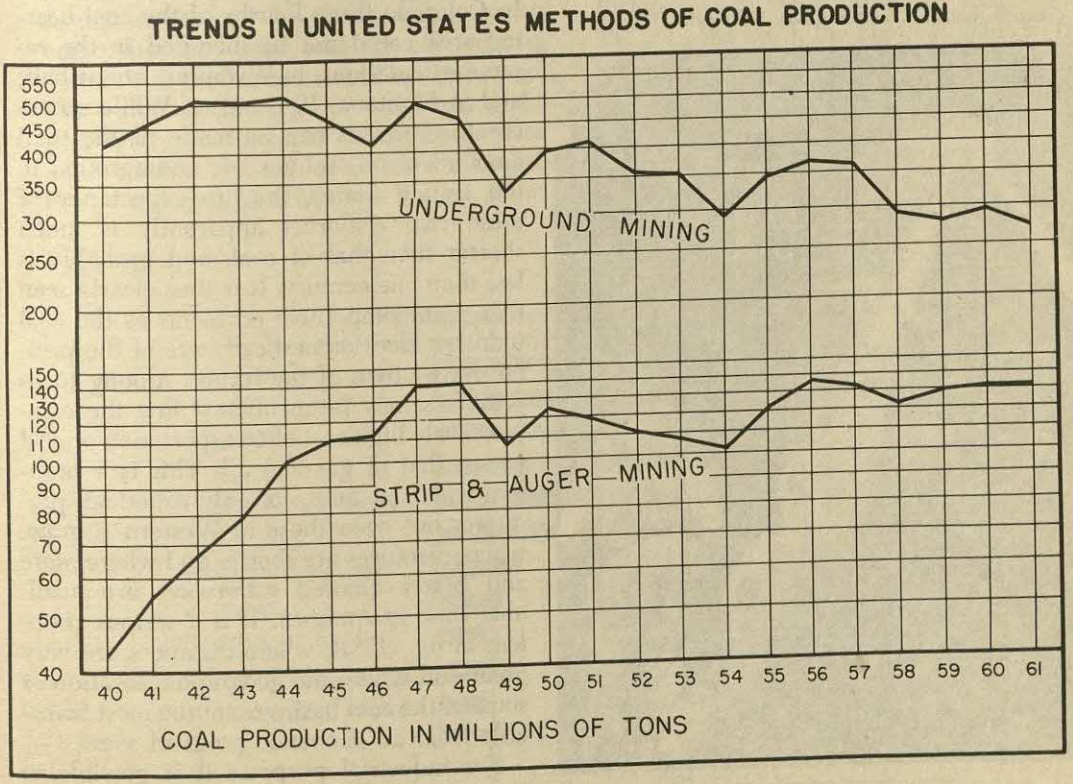
Some problems of the American coal industry. The coal-mining industry of the United States is capable of much greater production and may be expected to meet successfully any enlarged demand for coal that may come within the foreseeable future. In the past the coal industry has had to contend with strong seasonal fluctuations in demand. To meet peak demands, overexpansion of labor supply was induced with resultant unemployment during the slack periods. Seasonal fluctuations in demand have been overcome in considerable measure through a widely dispersed system

of storage of coal. It can hardly be expected that seasonal demands can be equalized, but they have changed from a curve of sharp peaks and drops to one of gentle undulations. Nevertheless, the average number of days worked by miners in the course of a year ranged from a low of 62 in Kansas to a high of 208 in Alabama in the year 1960, the average for the United States being 188. Efficiency of production has increased greatly. In 1930 production per man-day in all types of coal mines was about 5 tons, while at present it is over 12. Part of this rise is due to the increase in strip-mining. In some states where strip-mining is practiced man-day averages of 40 tons and over have been reached (for the entire United States the average is about 23 tons). However, there have also been great improvements in efficiency of operation in the underground mines. Three fourths of the underground coal is now cut by machines, and an increasing amount is mined by continuous mining machines, which load mechanically. Also, other forms of mechanical loading have become so common that at present only a small percentage of the coal is still loaded by hand (Figs. 247, 249).

Needless to say, the decreasing total coal production and the sharply increased production per man have resulted in a much smaller number of active miners. In 1923 the average number of miners employed was 856,000, but in 1960 the figure was only about 160,000. Many mining areas are now areas of chronic unemployment. This is true especially of the anthracite areas, but also of many of the mining counties of the Appalachian field in Pennsylvania, West Virginia, Ohio, Kentucky, and Virginia (Fig. 248).

Thus the American coal industry faces many problems, and the hopeful aspect is that the industry itself is cognizant of them. In 1960 the total estimated recoverable

Figure 247.



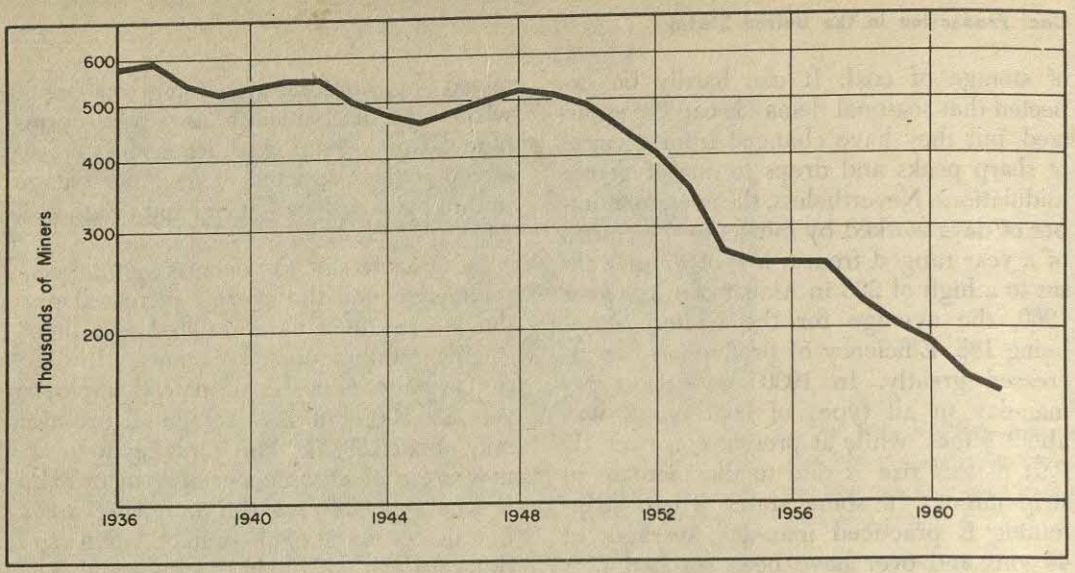
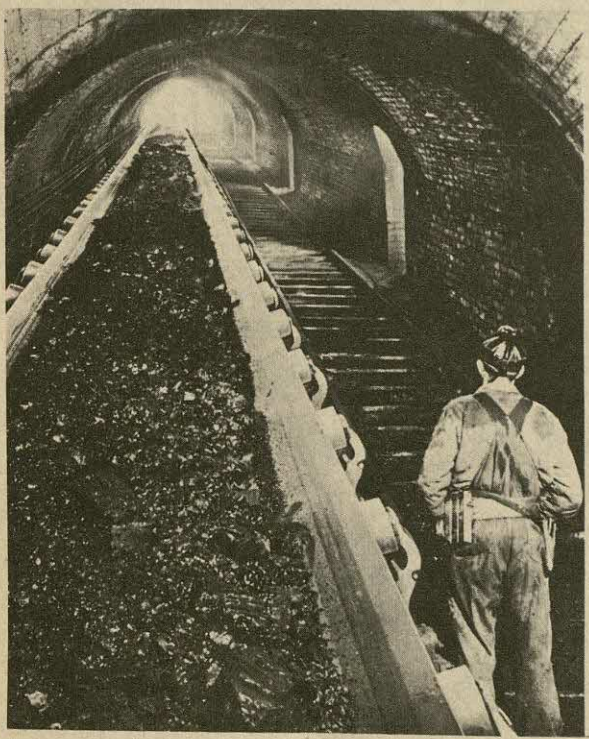


Fig. 248. Average number of miners employed annually in the bituminous and anthracite coal industries of the United States.

Fig. 249. View of the exit of a drift mine. Note conveyor belt transporting coal to the open.

Courtesy National Coal Association. Washington, D.C.



reserves of solid fuels in the United States were over 1,400 times recent average annual consumption. Actual reserves may be considerably larger, as the data available for a number of coal areas were insufficient. In Colorado three fourths of the coal-bearing area could not be included in the reserve calculations; in Wyoming, about half; and in Montana, 10 per cent. While no accurate estimates can be made of the total amounts of oil and gas left underground in the United States, the life expectancy of these two resources apparently is much shorter than that of coal, and probably is less than one century. It is thus clearly seen that such competitive problems as the coal industry faces domestically are of the present rather than of the future. Among these problems may be mentioned first the comparatively high cost of transportation of coal versus that of gas and oil. This is a problem which plagues not only American producers but even those in Western Europe, where distances are shorter and where more and better-oriented waterways are available than in America. It is a serious problem in the USSR, where distances are very great and where the geographic location of some of the coal basins is not the most favorable from an economic point of view.

For industrial purposes it is possible to

use coal in dust form. This has opened the way to coal transportation by means of pipelines: the coal is finely ground and mixed with water (or, perhaps, oil) to form a slurry, which then can be pumped. In Russia and in the United States extensive studies have been made of the practical possibility of underground gasification of coal, which would make mining unnecessary and which would make possible the distribution of the gas by means of pipelines.

In the United States and elsewhere, the competition of petroleum is especially serious along the seaboards, where water-borne, tanker-transported petroleum products have an advantage in all large coastal cities. In addition, port areas are natural areas to attract petroleum products, not only for inland distribution but also for use in ocean-going and coastal vessels, the great majority of which now run on oil instead of on coal, as formerly was the case.

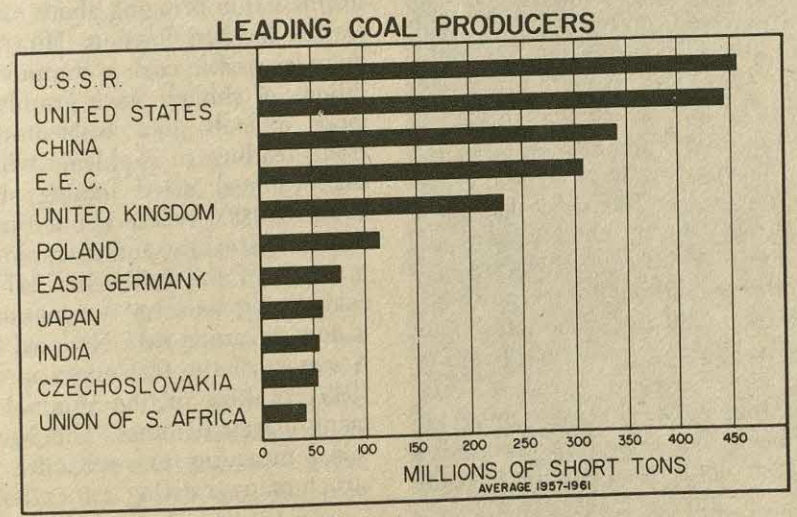
Much money is being spent by the coal industry in both the anthracite and bituminous fields for the promotion of research so that waste may be eliminated, by-products more fully used, and the efficiency of methods of production and of use improved. The value of this type of work cannot be expressed in dollars and cents at any given time because research must always be primarily a search for truth, not dollars. However, the net effects are shown in improved efficiency of production all along the line, from production in the depths of the mine to the manufacture of fine consumer goods, including textiles, drugs, and perfumes.

COAL PRODUCTION IN EUROPE AND ASIA

There are four major areas of coal production in Europe: (1) Great Britain; (2) the northwest continental area, which includes the Ruhr and other fields of West Germany and extends through the Netherlands and Belgium into northern France; (3) the Silesian field of southern Poland; and (4) the Donets Basin of southern European Russia. Secondary centers are the Saar district, the Moscow field, and the smaller producing fields of southern France, Czechoslovakia, Hungary, and Spain. Great Britain and Germany—mostly West Germany, to a lesser extent what is now East Germany—have long been the two leading coal producers of Europe (Fig. 253).

Great Britain. The coal fields of Great Britain are in four principal areas (Fig. 251). In the north the Scottish fields in the lowlands west of Edinburgh furnish fuel and power for the industrial heart of Scotland. To the south, in England, on the east side of the Pennine range, are the well-known producing areas of Newcastle

Figure 250.



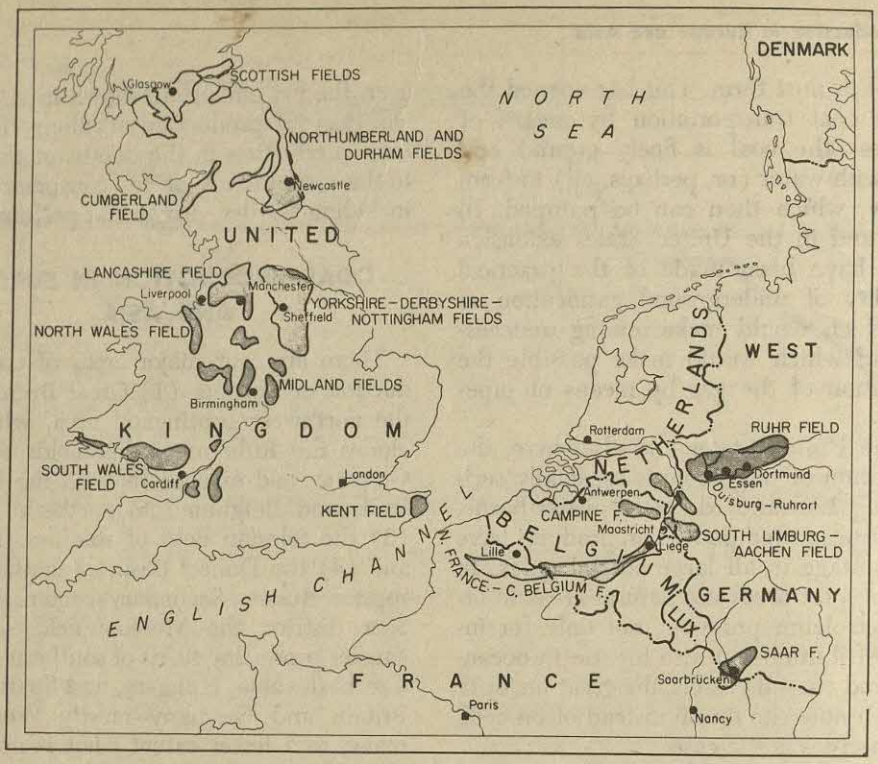


Fig. 251. Coal fields of northwestern Europe.

(Northumberland and Durham field) and the large Yorkshire-Derbyshire-Nottingham field, while on the west are the smaller fields that extend from Lancashire and North Wales to the Midlands around Birmingham (Fig. 251). In southern Wales is the Cardiff or South Wales field, which has the reputation of being the greatest field in the world for coal exports. The Yorkshire-Derbyshire-Nottingham field is by far the most important and produces more coal than all the other fields combined. Conditions of deposition are favorable especially toward the east, although depth of coal increases in this direction. Here are located some of the newest and largest mines, and average production in this field per man-day is higher than in all other British coal fields. The South Wales field still ranks second as producer, although conditions of mining are more difficult, production per man-day is considerably lower, and the area has been plagued with a great deal of chronic unemployment. Quite a number of mines have been closed in recent years. Also in the Scottish fields productivity is comparatively low, and a number of mines have been closed. In all of Great Britain conditions of coal occurrence are such that the possibilities for strip-mining are rather limited. At present only 7 per cent of the coal is mined in this manner. Great Britain is favored in the high quality of her coal and in the wide distribution of her producing fields. These factors have been largely instrumental in bringing about early and successful industrialization. However, as the more accessible coals were mined first, conditions of mining have gradually become more difficult, and costs have therefore risen, leading to problems which are not easily solved. Coal mining still employs about 650,000 workers, but the number is declining steadily, and unemployment exists in many of the fields. In 1947 the British coal-mining industry was nationalized and is now governed by a National Coal Board. A survey of the 950 mines in existence in 1949 resulted in the gradual closing of many marginal mines. The board has also taken measures to reorganize and reconstruct many existing mines and has sunk

new shafts, opened new drift mines, and increased mechanization of mining, as, for example, by increased use of machine cutting and machine loading.

Coal is still the basis of British industry and continues to be an important bulky export in British foreign trade. Since Britain has little water power and almost no petroleum or natural gas, coal is her chief domestic energy resource. However, the keen competition of oil which coal is meeting in all parts of the world is felt also in Britain. This competition was foreseen by British industrialists several decades ago and was responsible to a considerable degree for the energetic expansion of British capital and British industry into other areas of the world where reserves of petroleum were known to exist. As a result, imports of crude and processed petroleum into Great Britain have increased greatly, and here also coal is no longer undisputed master.

France, Belgium, and the Netherlands. In northern France and extending across Belgium into the South Limburg province of the Netherlands and the Aachen region of Germany lies an almost unbroken belt of coal fields containing high-grade bituminous coals and anthracite. Although coking coals occur in these fields, the amounts available are comparatively small, and both France and Belgium are in short supply of this commodity. Near Maastricht, but in Belgium, lies the Campine field, a northwestern projection of the generally west-east coal belt. Coal mining in parts of this major belt is old, in some sections dating back to the fifteenth century, when the coal was exploited on a small scale at outcrops. In most of the belt, however, the coal beds lie at considerable depth, are steeply inclined as a result of folding, and are discontinuous because of faulting. Most seams are comparatively thin. Unfavorable structural conditions render output per man-day low and prices high. This is true especially for some of the older Belgian mining regions. Conditions in France and the Netherlands are more favorable. In the newer Belgian Campine field the beds are much less disturbed, but the nonproductive overburden is thick, from 1,200 to 1,800 feet and more. Although the Netherlands imports much coal, it also exports, and before the war quantities involved were fairly well balanced. In recent years imports have exceeded exports.

In southern France there are a number of small coal basins on the flanks of the Central Plateau, such as the Loire or Saint-Étienne basin and the Bourgogne or Le Creusot basin. All are small and mostly of local or regional importance.

In all three countries shaft mining is the rule, some shafts reaching depths of 3,000 to 4,000 feet (Fig. 252).

West and East Germany. As the result of two unsuccessful wars, Germany not only was divided, but also lost its coal resources east of the Oder-Neisse line, including its part of the Silesian basin, one of the largest of the European coal basins. However, West Germany still has extensive reserves, varying in rank from lignite to high-grade bituminous. The Ruhr basin is by far the most important and is noted

Fig. 252. The above-ground portion of a large, modern underground mine in the Ruhr district near Herne, Germany. Note its location on the Rhein-Herne canal. Workers' homes in foreground. In this part of the Ruhr district mining and farming are still carried on in close proximity. The mine hoists, typical for a shaft mine are not easily visible in this oblique air photograph.

Courtesy Hansa Luftbild Amt



especially for its coking coals and highly volatile bituminous types. Ruhr or Westphalian coking coal is in demand throughout much of continental Europe west of the Russian territories. Since the mines are not far from the Rhine river, much coal is transported upstream by barge to southern West Germany, France, and Switzerland, and downstream via the Netherlands to other countries (Fig. 251).

Structurally, the Ruhr basin is more favorable to mining than are the Belgian and French fields. The beds lie in rather open southwest-to-northeast trending folds, but are intersected by a number of major faults that run in a southeast-northwest direction. Major faults are responsible for the gaps between the individual fields southwest of the Ruhr basin. The coal measures outcrop in the southeast, near the Ruhr river, a right bank tributary of the Rhine. In this section, however, much of the coal is gone. Mining has moved northwestward, where the overburden increases in thickness, but where the strata become more level and the beds thicker. Shaft mining is, of course, necessary. The individual seams are of moderate thickness, but commercial coal occurs in about 95 beds, averaging 43 inches in thickness each. Before the war the Ruhr basin provided almost two thirds of total German requirements of bituminous coal. This percentage has of course, risen greatly since the partition of Germany. The Ruhr is one of the most densely populated industrial areas of the world (Fig. 365), and although it was heavily bombed during World War II the area has been rebuilt. Before the war it produced more metallurgical coke than any other area or country, outside the United States. The proximity of the Rhine and the construction of canals and a dense network of railroads and roads have made it possible to ship raw materials in and out of the area at low cost.

The Aachen field, near the city of that name, is small, and continues northwestward into the Dutch South Limburg field and the Belgian Campine field (Fig. 251).

On the French-German border, near Saarbrücken, lies the well-known Saar basin, a comparatively small field but one with high-quality coals (including some coking coals), fairly favorable mode of occurrence, and large reserves. Because of German destruction of coal mines in northern France during World War I this area was separated temporarily from Germany and administered by the League of Nations, with the coal mines controlled by the French state. Also after World War II the Saar was again given temporary status in favor of France, but is now part of West Germany.

Large lignite or brown coal deposits are found in Saxony, particularly in the Leipzig-Magdeburg area, now in East Germany, in the Cologne region of West Germany, and in Bavaria, West Germany. The bulk of the production is in Saxony, East Germany. The beds are extensive and of considerable thickness. Most of the lignite can be produced by open-pit mining at a very low cost per ton. Even though Central Europe has a large production of bituminous coal, the importance of the brown coal deposits to the industrial life of the nation concerned can hardly be overemphasized. The lignite is converted into electric power on a large scale. It is made into briquettes for household and industrial use, and it also serves as a major raw material for the manufacture of synthetic gasoline and a number of chemical products.

The European Coal and Steel Community. On the European continent coal is still the basis for industry to such an extent that the attempts at closer economic and other forms of cooperation—aiming at the creation of the presently developing European Economic Community—were first made in the field of coal and steel production.

In April, 1951, under a treaty between Belgium, France, West Germany, Italy, Luxembourg, and the Netherlands, the European Coal and Steel Community was formed for the purpose of creating a common market for coal and steel by abolishing tariff duties and other quantitative restrictions on the movements of these two commodities within the countries concerned. This was a great step ahead in the economic life of Western Europe since many political boundaries intersect a coal and indus-

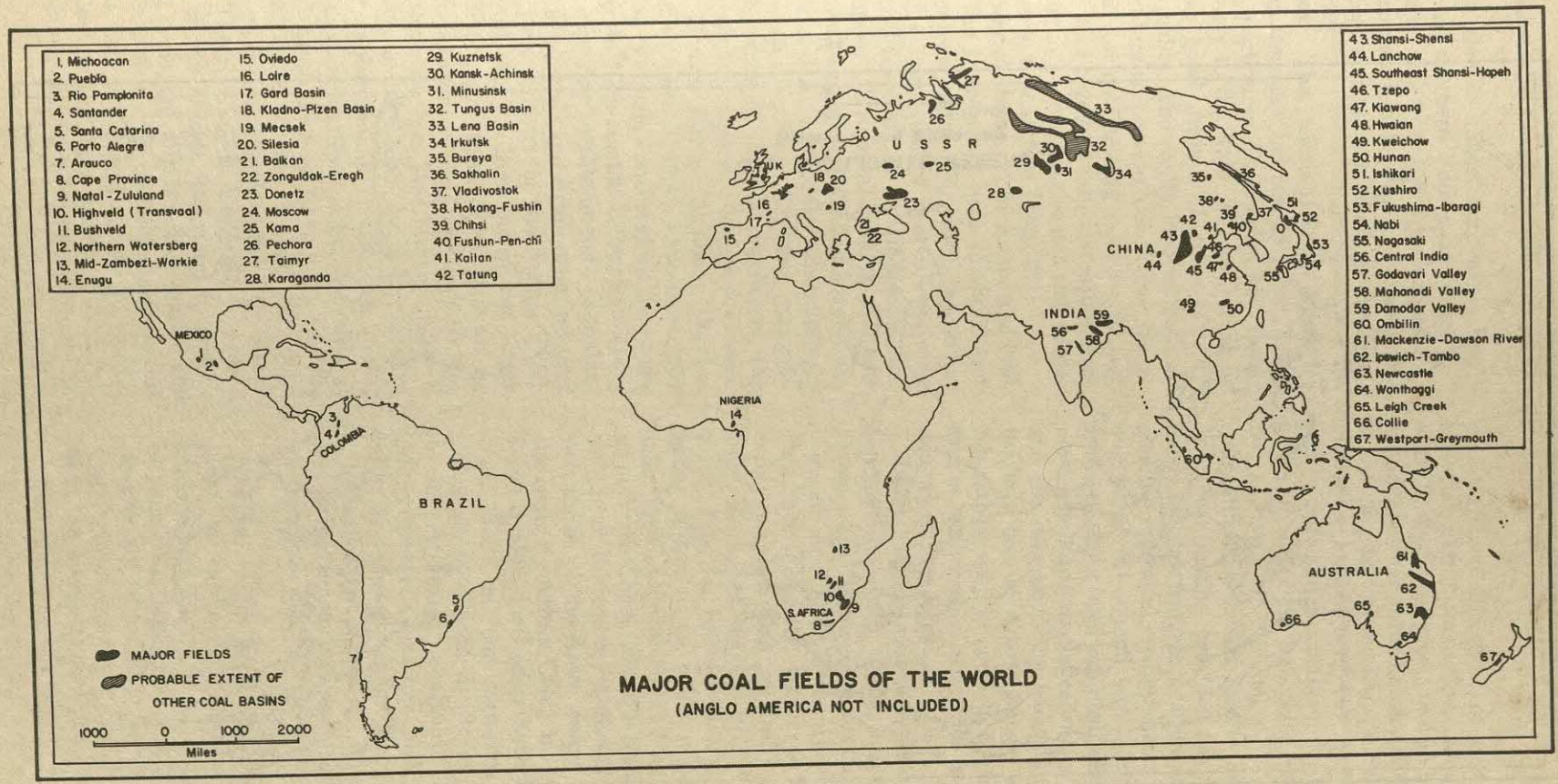

1. Michoacan
2. Puebla
3. Rio Pamplonita
4. Santander
5. Santa Catarina
6. Porto Alegre
7. Arauco
8. Cape Province
9. Natal-Zululand
10. Highveld (Transvaal)
11. Bushveld
12. Northern Watersberg
13. Mid-Zambezi-Workie
14. Enugu
15. Oviedo
16. Loire
17. Gard Basin
18. Kladno-Pizen Basin
19. Mecsek
20. Silesia
21. Balkan
22. Zonguldak-Eregh
23. Donetz
24. Moscow
25. Kama
26. Pechora
27. Taimyr
28. Karaganda
29. Kuznetsk
30. Kansk-Achinsk
31. Minusinsk
32. Tungus Basin
33. Lena Basin
34. Irkutsk
35. Bureya
36. Sakhalin
37. Vladivostok
38. Hokang-Fushin
39. Chihsi
40. Fushun-Pen-chi
41. Kailan
42. Tatung
43. Shansi-Shensi
44. Lanchow
45. Southeast Shansi-Hopeh
46. Tzepo
47. Kiawang
48. Hwaian
49. Kweichow
50. Hunan
51. Ishikari
52. Kushiro
53. Fukushima-Ibaragi
54. Nabi
55. Nagasaki
56. Central India
57. Godavari Valley
58. Mahanadi Valley
59. Damodar Valley
60. Ombilin
61. Mackenzie-Dawson River
62. Ipswich-Tambo
63. Newcastle
64. Wonthaggi
65. Leigh Creek
66. Collie
67. Westport-Greymouth
MEXICO
COLOMBIA
BRAZIL
U S S R
UK
CHINA
INDIA
NIGERIA
S.AFRICA
AUSTRALIA
MAJOR FIELDS
PROBABLE EXTENT OF OTHER COAL BASINS
1000 0 1000 2000
Miles
MAJOR COAL FIELDS OF THE WORLD
(ANGLO AMERICA NOT INCLUDED)

Figure 253.

COAL AND LIGNITE RESERVES
(LIGNITE IN COAL EQUIVALENT)
1000 0 1,000 Miles
BILLIONS OF TONS
2,500
1,500
500
100
25
5
Under 1
ALASKA
CANADA
U. S. A. (WITHOUT ALASKA)
COLOMBIA
PERU
CHILE
W. & E. GERMANY
UNITED KINGDOM
BELGIUM
FRANCE
SPAIN
NORWAY
POLAND
CZECH.
HUNG.
ROMANIA
U.S.S.R.
SOUTH AFRICA
SOUTH RHODESIA
INDIA
CHINA
N. & S. KOREA
JAPAN
AUSTRALIA

Figure 254.

trial area that is almost continuous from Bethune in northern France to Hamm in Westphalia, and there was a great need for the unhampered exchange of various qualities of coal and types of steel across these boundaries.

Poland. The Silesian field, formerly largely in Germany but now in Poland with a small portion in Czechoslovakia, ranks second only to the Ruhr. The coal there is known as good steam coal, some of it of coking quality. The gently inclined beds at shallow depths provide conditions favorable for low-cost mining operations, and these factors together with increasing market demands have given rise to a rich industrial area in that section (Fig. 253).

The Soviet Union. The reserves of coal within the tremendous area of the Soviet Union are very large (Fig. 254), but on the basis of energy content over 85 per cent of the coal is located in Asiatic Russia, east of the upper Ob river, and still farther east and north, along the middle and lower Yenisei river and its east bank tributaries and in the Lena river basin. This is a long way from the area of densest population, the great triangle Leningrad-Sverdlovsk-Odessa.

The Donets Basin (Donbas), located north of the Sea of Azov, is the most fully exploited of Russia's coal regions. The coals range from high-volatile bituminous (over 31 per cent dry volatile matter) to anthracite. Coking coals and steam coals are used in the steel industry of the region, which obtains its iron ore from the nearby Krivoi Rog ore deposits. Some of the Russian anthracite is exported and even finds its way to Western Europe. The Moscow basin is extensive, but the coals are of low quality, mostly subbituminous. Production in the Urals is comparatively large, but reserves are not great. The opposite is true of the Pechora field, located beyond the Polar Circle on the west flank of the Ural Mountains. The reserves are reported to exceed those of the Donets Basin and to include coking coals, but distance from market and high cost of mining under permafrost conditions limit its importance to production for Leningrad and the northern and northwestern regions. In Asiatic Russia coal mining has been greatly expanded in the Kuznetsk Basin, where Novokuznetsk (formerly Stalinsk) has grown into an important industrial center; in the Kansk-Achinsk basin to the east; and in the Karaganda basin of Turkestan, located northwest of Lake Balkhash. Both the Kuznetsk and Karaganda basin are important for coking coals (Fig. 253).

Around Irkutsk and in the Soviet Far East coal mining provides for the local needs of a growing population and of expanding industrial establishments and various types of mineral exploitation. Thus while Russia is well supplied with coal, its main handicaps are the enormous distances and the necessary long hauls. This is particularly true of Asiatic Russia, where the Siberian rivers run north to the icy Arctic Ocean, rather than westward toward the centers of population.

China. Huge coal deposits have been reported to exist in China, and early estimates placed Chinese reserves on a par with those of the United States. However, later data have shown the reserves to be considerably smaller than originally estimated (Fig. 254). The deposits are widely scattered, but the better qualities occurring under relatively favorable mining conditions have been exploited in Manchuria and in northern China, with the result that this section of the country ordinarily produces two thirds of the entire output. Although the coals of southern China are generally of lower quality, local areas have high-grade coal. These, in most instances, occur in rather steeply folded structures giving rise to difficult mining operations. The present government of China has made an all-out effort to increase coal production, and it is estimated that at present Chinese production of bituminous coal, anthracite, and lignite is not far behind United States production.

Japan. Many small coal fields occur in Japan, particularly in Honshu and Hokkaido, where quality varies from low-grade bituminous to high-grade coking coal. The reserves are estimated to be not more than 1 per cent as great as those of China. Despite the energetic enterprise of the Japa-

nese and up-to-date mining methods, the coal fields have been found inadequate to serve the industrial needs of the country, and hence imports have been necessary in the past and unquestionably will be necessary in the future if the industrial life of Japan is to prosper.

India. In northern and central India (see Figs. 253 and 254) the reserves are estimated to be at least four or five billion tons of easily accessible, high-quality coal, a third or more of it being of coking quality. While smaller fields are found in other parts of the country, the Bihar and Orissa fields are the largest and most promising for continued exploitation in the near future. Iron ore and coal are within easy reach of each other, a condition which seems to warrant the expectation of further development of industry in northern India. However, Indian production ranks approximately with that of France and is probably only about one seventh of Chinese production. This is not large for a country of India's size and population.

COAL PRODUCTION IN OTHER CONTINENTS

The production of coal by the principal countries of the world, as shown by Fig. 250, shows clearly that the Northern Hemisphere holds almost a monopoly in this line. South America has small, widely scattered reserves. Inasmuch as coal can be imported at relatively low cost and the petroleum industry is expanding, the near future does not seem favorable to significant expansion in South American coal production, even if further exploration should reveal the existence of other deposits. At present Chile, Colombia, and Brazil are the only countries with substantial output, although coal is known to exist in a number of other areas. There has been considerable development in South Africa, with production of bituminous coal and anthracite reaching between 40 and 50 million tons. Elsewhere in Africa both deposits and production are small. Australia and New Zealand produce bituminous coal and lignite, but only on a modest scale. Development is handicapped by lack of both labor and markets. Largely because of the youthfulness of the two countries, industrialism has not reached the stage of development common in some of the older nations. As demand increases, the coal-mining industry of Australia, New Zealand and South Africa may be expected to keep pace, but there is little prospect of rapid progress in the near future.

THE FUTURE OF COAL

Has coal been dethroned? The answer to this question depends on where one is,

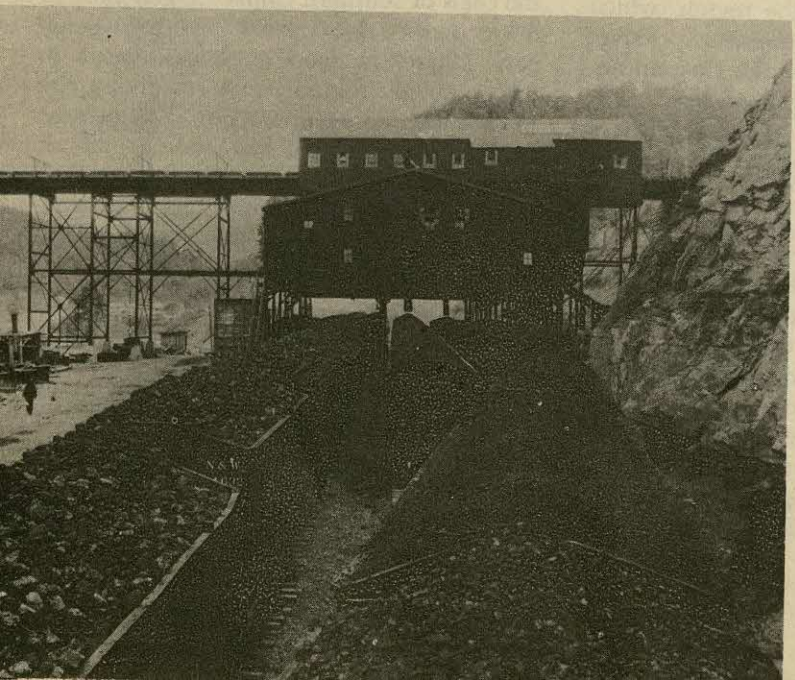
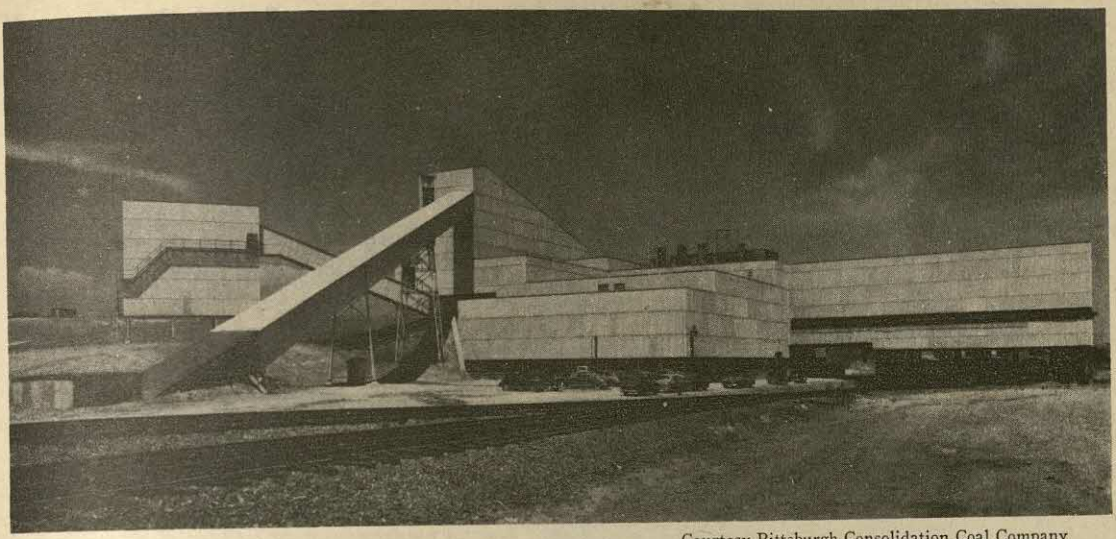


Fig. 255. Bituminous coal of different sizes being loaded into railway cars from the sorting screens of the tipple. This is a common sight in many of the bituminous fields.

Courtesy Bituminous Coal Institute, Washington, D.C.



Courtesy Pittsburgh Consolidation Coal Company

Fig. 256. The world's largest preparation plant, or tipple, for cleaning, sizing, washing, and sorting raw coal as it comes from the mines to meet consumer needs. Capacity 1,500 tons per hour.

and how one looks at things. In the United States coal has ceased to be undisputed monarch, and in a number of other countries its rule has weakened or is weakening. Nevertheless, total production of coal has continued to rise; in many countries coal is holding its own, and from a world point of view—or even from an American point of view—it still is of enormous importance as a source of energy and a source of by-products. Finally, unless unforeseen developments occur, coal is likely eventually to gain back some of the status it has lost. All evidence available at present tends to show that world resources of coal are destined to outlast those of gas and oil.

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22

Petroleum and Natural Gas

highly mobile sources of power

In the United States the car, truck, tractor, and plane—all petroleum-driven vehicles—are responsible for some of the greatest changes that have taken place since the invention of metallic, steam-powered machinery, and since the coming of the railroad: for the drift of population from rural areas to the cities, for the tremendous growth of metropolitan areas, for the phenomenon of cities practically turning themselves inside out, and for radical rearrangements in the patterns of transportation of goods and persons. Elsewhere in the world petroleum and its products are also effecting changes in man's various modes of life—even villages in the African bush are becoming integrated with the modern world by means of trucks and jeeps.

While to many of us petroleum is primarily a term that specifies the source of motor fuel and lubricants, it behooves us to realize that crude oil and its close relative, natural gas, have become basic materials for hundreds of items obtained as chemical by-products of the refining industry. Some of the largest petroleum and natural-gas companies have organized separate large-scale chemical plants which in many places are conspicuous features of the landscape, particularly along the Gulf coast of the United States. Thus petroleum, the medicinal "rock oil" advertised by quacks of the early nineteenth century, has become an industrial giant in the twentieth century, a giant in diversity of products as well as in industrial stature.

Although its rise to a position of industrial prominence has been recent and of meteoric speed, petroleum has long been known to man since oil seepages occur in many parts of the world. Tar from petroleum seepages is reputed to have been used in constructing the tower of Babylon and for burial procedures by the ancient Egyptians. It may have been responsible, in some measure at least, for the success of the Phoenicians in sailing their light craft throughout the Mediterranean and even beyond, as tar, used for calking, made their vessels more seaworthy. Petroleum was used as an ointment by the people of ancient Mesopotamia long before the beginnings of the Christian

era; in the New World the Indians of Pennsylvania and New York utilized it for medicinal purposes. Its use in industry, however, had to await the discovery of a method for obtaining large quantities of petroleum by drilling through considerable thicknesses of hard rock. To Colonel E. L. Drake must be given the distinction of being the first to work out and attempt this method.

In some places oil from seepages had even been used as a source of heat and light. Marco Polo in the thirteenth century noticed oil seeps in the Caucasus area. This oil was said to be not good for use with food, but to be good for burning, and also for anointing camels that have the mange. Use in lamps led to a growing demand for oil because of the scarcity of animal or vegetable fats suitable for use as illuminants. In order to obtain larger production, hand-dug wells were attempted. In most cases these met with indifferent success, but in Burma they early yielded satisfactory results. Thus, Rangoon oil became a significant article of commerce in London early in the nineteenth century. Hand-dug wells by that time were also numerous in Romania. Before there was an American petroleum industry, oil refining to obtain kerosene and lubricants had begun.

Although there was early knowledge of the presence of oil in western Pennsylvania, its uses were not well understood, and demand grew slowly. Before the middle of the nineteenth century, however, the use of oil for ointments, and to some degree for lamps, had expanded to such an extent that the price for the small available supplies had reached phenomenal heights. This condition attracted attention, and companies began to be formed for the exploitation of the "rock oil." As it was an entirely new field, all the techniques of exploitation and refining had to be learned. Drilling through hard rock was the first problem to be solved.

In 1859, near Titusville, Pennsylvania, Colonel E. L. Drake rigged up a crude drilling apparatus based upon the principle of crushing the bedrock into minute particles by successively raising and dropping a heavy iron rod equipped at its lower end with a hard, sharp bit. By this trip-hammer method, he drilled his well to a depth of 69 feet, obtaining a yield of about 40 barrels a day, but which dropped to 15 barrels a day before the end of the year.[1] This was the first well to be drilled mechanically for the express purpose of obtaining petroleum (Fig. 257). The exact location of the well was chosen on the basis of seepages found nearby along the banks of Oil Creek. At first the petroleum produced by the discov-

[1] The "barrel" of petroleum is a commonly accepted unit of measurement and has a content of 42 gallons.

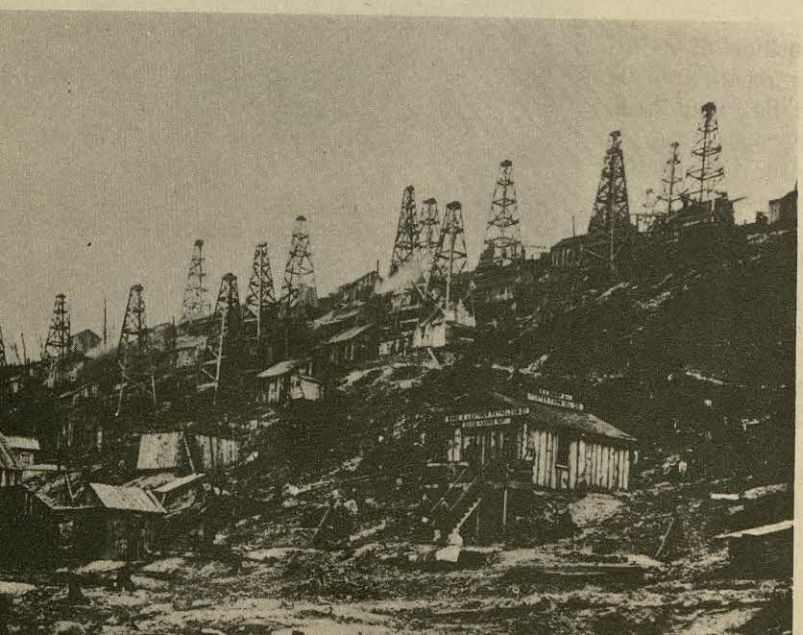


Fig. 257. The world's first "oil boom." Edwin L. Drake brought in the first commercial oil well in northwestern Pennsylvania (at Titusville), and this started the first development illustrated here.

Courtesy Texas Company

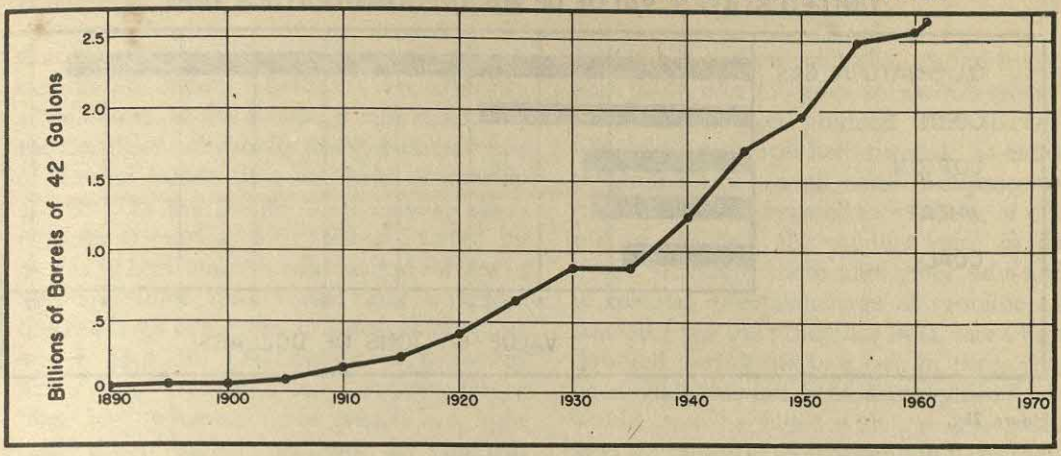


Figure 258.

ery well was sold at over $20 per barrel, but soon other wells were drilled, and so much oil was obtained that prices collapsed. These early incidents marked the first instance of "boom and bust" in the petroleum industry. Through a long and active career Drake lived to see the industry become an industrial giant, but he died a poor man—a fate not uncommon to the pioneer.

IMPORTANCE OF PETROLEUM

Economic importance. The art of drilling for petroleum through solid rock, thus inaugurated in western Pennsylvania by Drake, made oil available in quantity and marked the beginning of a new industry. However, the beginning remained modest for a number of decades. Early refining was a simple distillation process, and only the fraction which became known as kerosene was deemed to be of marketable value. And the kerosene lamp, even though designed in such a manner as to avoid danger of explosion, had to overcome considerable prejudice. Such was the beginning of the oil industry here and abroad. Internal-combustion engines were still in the dream stage.

As may readily be observed from Fig. 258, the production of petroleum in the United States increased steadily but not rapidly until after the close of the nineteenth century. Since that time, however, petroleum production and the development of industries attendant thereupon have proceeded at a continually accelerated pace in the United States and abroad. Since 1860, when the industry started from "scratch," it has, in the United States and the other producing areas, grown to represent a huge investment. Yearly production in the United States increased from a few barrels in 1859 to 64 million barrels in 1900, and to over 2,500 million barrels in recent years. From the point of view of value of output, petroleum has assumed the rank of the most important commodity produced by the United States in the realm of either mineral or agricultural production (Fig. 259).

Industrial importance. The expanding production of petroleum has, of course, been due to the varied uses to which its products are adapted—uses which have, in turn, resulted from chemical discoveries and from the instruments, machinery, and general equipment which science and engineering have brought into being. A legion of secondary industries has developed in connection with the production of petroleum. In the realm of transportation, industries which now have been organized into separate corporations include those constructing and managing pipelines, tank cars, and ocean tankers, while in the realm of manufacture they include those producing diesel engines, automotive engines, jet planes, chemicals, and drugs. All these and many other products have given rise to great industrial plants providing demands for labor ranging through the whole category from unskilled to highly scientific and, within the realm of management, from fore-

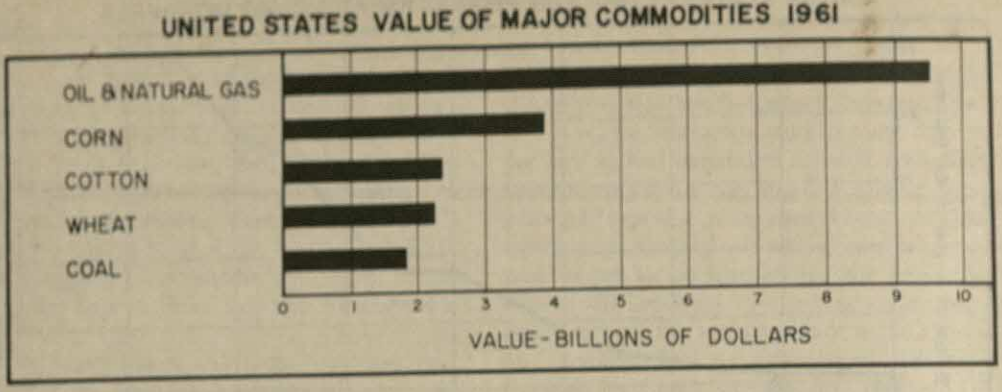


Figure 259.

men to top executives. The petroleum industry now includes some of the greatest corporations in the world, but it is not limited to such, for it also includes thousands of smaller corporations which may properly be termed small businesses. This whole structure, however, has become so intimately interwoven into the fabric of economic life that whatever affects its welfare, favorably or adversely, has its repercussions upon the well-being of all. Petroleum has become an essential business factor in peacetime and a military necessity in time of war.

With recognition of some of the factors that have been involved in the development of the petroleum industry from the earliest period to the present and with appreciation of the position now reached, we may well raise such questions as: Under what conditions does petroleum occur? To what processes must it be subjected to prepare it for the varied uses now demanded of it?

PROPERTIES OF PETROLEUM

Petroleum means literally *rock oil*, a name given to it because the seepages were found in rock and some people believed that the oil was something that was oozing out as it was being produced in some mysterious manner immediately within. Technically, however, petroleum is a mixture of liquid, gaseous, and solid hydrocarbons, of which the latter two are wholly or partly in solution in the first. By hydrocarbons is meant a group of compounds consisting essentially of hydrogen and carbon chemically combined in varying proportions. The mixture may contain so many different kinds of hydrocarbons that the abilities of the chemist must be utilized in order to recognize or separate them.

The large number of different mixtures gives rise to numerous kinds or grades of crude petroleum. Light oils have low percentages of carbon and high percentages of hydrogen, whereas in the heavy oils the reverse holds true. Therefore, light oils, such as the gasolines and light naphthas, are usually much richer in the lighter hydrocarbons than are the heavier fuel oils. Since the lighter hydrocarbons are in greater demand, it may be said that in a general way the value of petroleum increases as its density decreases.

Petroleum varies in color from light straw to almost black. Some kinds are greenish, others amber-colored, and some even a rich wine red. In general, high-grade crude is light-colored and greenish, whereas the heavier grades are brown to black. With respect to the residue which results upon evaporation or refining, crude petroleum is classified into three groups: paraffine-base, asphalt-base, and mixed-base oils. The paraffine-base oils are ordinarily lighter and more fluid than are those with an asphalt base.

The density is expressed in terms of specific gravity or in terms of its equivalent on the Baumé scale. Specific gravity of crudes varies from 0.77 to 1.00, but ordinarily it ranges between 0.82 to 0.94. The direct specific gravity scale is open to the objection that it deals with fractions and

that the numbers are neither read nor remembered easily. Therefore, an arbitrary scale known as the Baumé is employed, and the densities are usually designated in terms of Baumé rather than in terms of specific gravity. On the Baumé scale specific gravity 1.00 is read as 10°. Oils are tested by means of hydrometers constructed for use in liquids lighter than water, and therefore the readings are given in integral numbers larger than 10. Oils nearly as heavy as water have readings only slightly larger than 10°, whereas those which are light have much higher readings. In common trade usages, crude oils which give a Baumé test below 20° are known as *heavy*, whereas those which test above 30° are *light* oils.

FUNDAMENTAL ASPECTS OF PETROLEUM REFINING

Petroleum refining has been improved to such an extent in recent years that it can no longer be termed a process of mere distillation; it has developed into a chemical industry of the first magnitude. Formerly it was generally understood that "gasoline was gasoline," but now we know that there are various grades of gasoline, each differing essentially from the others. Gasolines of specific qualities now are supplied for use in motors operating under different mechanical and weather conditions.

Improvements in the processes of refining have been made to obtain products of higher quality. Also there has been great progress in making more complete use of crudes formerly deemed undesirable. Heavy oils can now be converted into lighter oils by means of *cracking* or *hydrogenation*. The basic principle of the first process is the splitting up of larger molecules into smaller, lighter ones. That of the second is heating the oil under pressure in the presence of free hydrogen. The ratio of the hydrogen to the carbon is thus increased and the petroleum converted into a lighter grade, the quantity of gasoline obtainable being increased thereby. On the other hand, some crudes have associated with them gases known as wet gases that are too light for practical use, in which case the problem is one of decreasing the ratio of hydrogen to carbon in order to manufacture a somewhat heavier product. This likewise has been accomplished through so-called *polymerization*. In all cases the processes give rise to an increased percentage of output of gasoline, the product most in demand. Through these and other advances in refining, the percentage of gasoline extracted from the crude has been more than doubled during the past two or three decades. Had this not been accomplished, we would now be faced with gasoline shortages in the world, notwithstanding the enormously increased production of crude.

Petroleum, through the developing techniques of refining, has become a basic raw material for a great variety of chemical products varying from asphalt to medicinal products. Among such products none is more vital to industry than the lubricants. In fact, some scientists have been concerned more about threatened shortage of lubricants than of motor fuels. Should petroleum reserves be depleted, the problem of obtaining liquid fuels from sources other than petroleum appears more readily solvable than does the problem of obtaining high-grade lubricants. The refining industry has succeeded marvelously well in providing lubricants from petroleum to meet requirements of nearly all types of machinery. The efficiency of modern machines used in agriculture, industry, and transportation must be attributed in large measure to the high-quality lubricants now available.

MODE OF OCCURRENCE, ORIGIN AND RECOVERY OF PETROLEUM

Mode of occurrence. Most of the petroleum of the world occurs in sedimentary rocks, in the tiny pore spaces that exist especially in sands, sandstones, conglomerates, and limestones. Shales and clays may also contain oil, but as these rocks are quite impermeable it is difficult to extract the oil. Open-textured permeable sandstones are perhaps the most common reservoir rocks, although in many cases notable production has been obtained from porous or cavernous limestones. Petroleum is rarely found in ig-

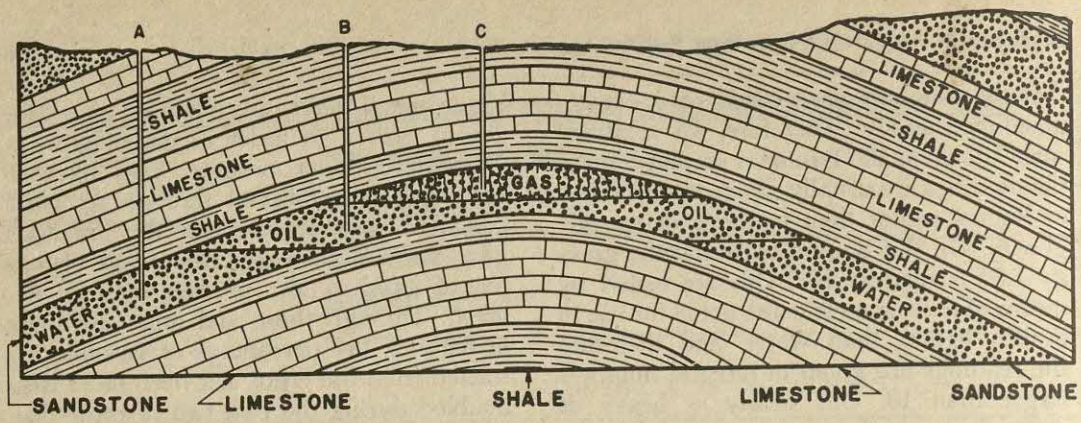


Fig. 260. An oil- and gas-bearing anticline. In this case note that shale is the cap rock and sandstone is the reservoir rock. Wells A, B, and C have all tapped the reservoir rock but with different results.

neous rocks, and in the few known cases the migration of the petroleum from adjacent sedimentaries into the igneous rocks has been clearly proven. Also metamorphic rocks are not sources of petroleum as the heat and pressure to which these rocks have been subjected would have destroyed any oil that might have been present.

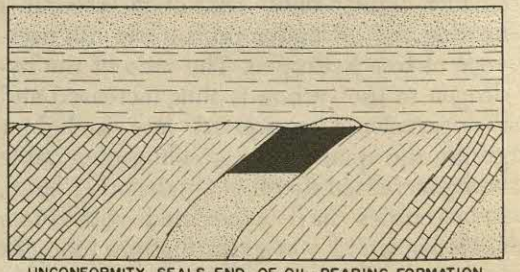
Thus sedimentary rocks, particularly those deposited in a shallow marine environment, are the best sources. The thicker the accumulations of sedimentaries are, the better are the chances of finding oil or gas in them somewhere. In favorable localities two, three, four, or more strata may be found that contain oil in commercial quantities, so-called *oil horizons*. Accumulations of oil and gas in considerable volume usually do not occur in flat-lying rocks, but rather where the strata have been more or less disturbed, such as by gentle folding or faulting, and where so-called *structures* have been formed.

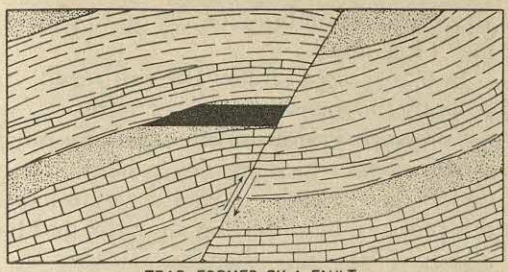
Anticlines are perhaps the best-known structures favorable for petroleum accumulation (Fig. 260). Where that type of structure is found in petroliferous areas, natural gas may occur in the apex of the anticline, petroleum in the upper flanks, and water at the lower levels. This sequence, however, does not necessarily follow, because often no free gas is found in the apex, even when the petroleum exists under pressure, because in a large number of cases the gas is dissolved in the liquid petroleum found in the interstices of the reservoir rock.

The general sequence, however, of water, oil, gas, or gas dissolved in the oil is the condition commonly found. The necessary structural conditions are that there must be present: (1) petroliferous beds from which the petroleum has been derived, (2) a porous and permeable reservoir rock for the accumulation of the oil and gas particles, and (3) an impermeable cap rock which prevents escape or dissipation of the petroleum and gas. The reservoir rock sealed by a cap rock may give rise to what is called a *petroleum trap*. Such traps occur not only in anticlines, but also under various other structural conditions, some of which are illustrated in Figs. 261 to 263.

Origin and recovery of petroleum. The mixture of hydrocarbons known as petroleum is believed to be of organic origin

Fig. 261. A petroleum trap is sealed by flat-lying sedimentary rock deposited over an ancient, eroded surface of steeply pitching beds. The upper, flat-lying beds have fine-grained shales at the base, preventing upward escape of oil and gas.





TRAP FORMED BY A FAULT

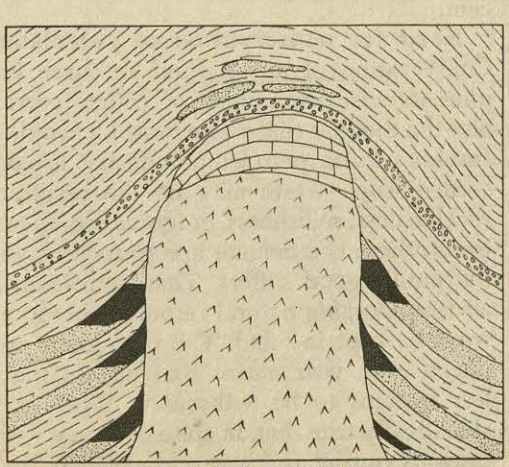
Fig. 262. Petroleum accumulation in a sandstone "trap" caused by a fault in tilted strata. A fault is a structure wherein strata have been broken and displaced. In this case the arrows indicate the vertical displacements.

and to have resulted from the decomposition of microorganisms of plant and animal nature. It is found in the pore spaces of rocks where structures gave rise to traps in which the minute droplets accumulated and were prevented from escaping by impervious cap-rock strata. Since there are no "rivers of oil," the explanation of how wells become producers, ranging from slow-yielding pumpers to spectacular gushers, must show how oil is obtained from the millions of tiny interstices of the reservoir rock. Although man must often help bring the oil to the surface by pumping, nature often provides considerable force or pressure.

Such pressure may be caused by water or by gas. In some cases the water that exists in an oil structure is under artesian pressure, and this pressure will be communicated to the oil present at a higher level in the structure (oil is lighter than water). A well drilled into the oil-containing portion of the structure will yield a flow of oil, whereas if it were drilled farther down in the structure it would yield water only (Fig. 260).

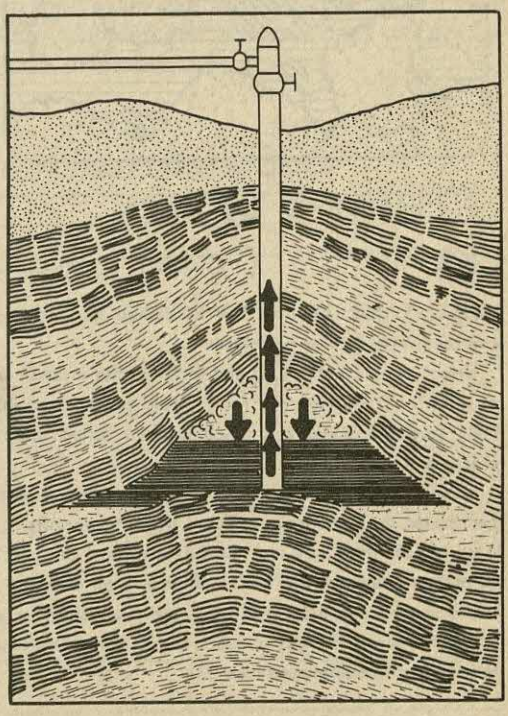
More commonly, pressure is exerted by hydrocarbons in gas form. If a well is drilled near the crest of a structure wherein free gas exists above the oil, a "gasser" results. If it is drilled into the oil-containing portion of the structure, the pressure of the gas

Fig. 263. Salt plug or dome structure with petroleum reservoirs in tilted strata sealed with the core. Structures similar to this are common in the Gulf Coastal plain but not all are petroliferous.



OIL TRAPPED AGAINST SIDES OF SALT PLUG

Fig. 264. Illustration of how pressure of free, confined gas in the upper part of an anticline may cause oil to issue as a flow well or a gusher from the underground reservoir. Note that the cap rock is a dense, fine-grained stratum.



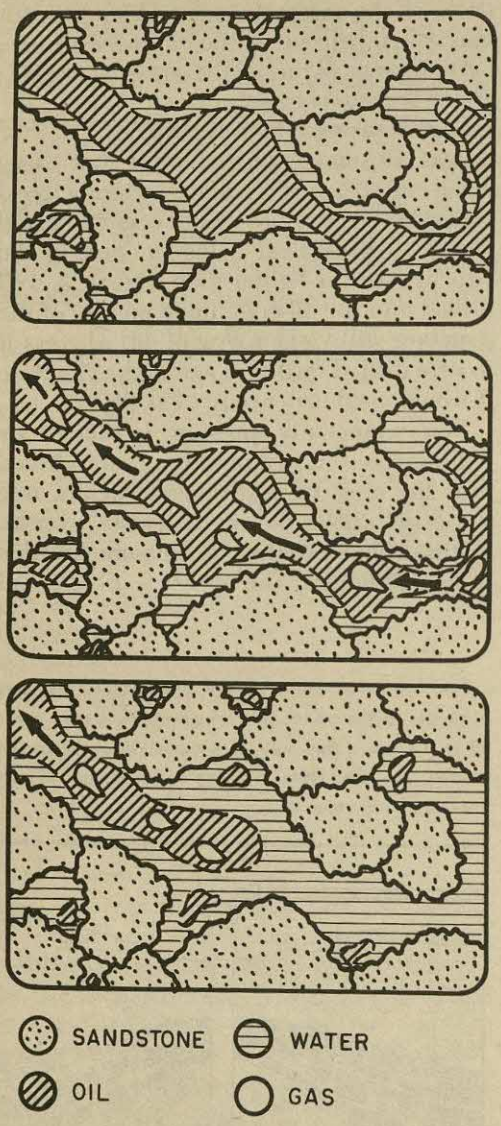


Fig. 265. Illustration of how contained gas induces and facilitates flow of petroleum.

Upper diagram shows oil and water in the interstices of sandstone, the reservoir rock. Liquid petroleum contains much dissolved gas which remains liquid under pressure.

Middle diagram shows what happens when a well penetrates the sandstone; reduced pressure permits release of contained gas and this moves toward the point of pressure release, the well, and pushes oil with it.

Lower diagram, after well has been producing for a long time, shows the gas pressure nearly gone. The well then becomes a slow producer.

above will aid in bringing the oil to the surface (Fig. 264).

In many cases oil flowage will result apparently independent of either water or free gas pressure. Petroleum often contains much dissolved gas which remains in solution only under some pressure. A well serves to lessen this pressure by providing an outlet and the dissolved gas may then be released at a rapid rate. The petroleum may also emerge as a flowing well or even as a gusher. Flowage will continue as long as the oil contains dissolved gas, which by its release and resultant expansion serves as a force to induce movement of the oil through the small pore spaces of the reservoir rock and into the well (Fig. 265).

The foregoing paragraph is designed to help readers to understand why it is important to maintain strong gas pressure in oil wells as long as possible. Control of pressure does imply that the early flush production will be held to a rate lower than could be obtained if the wells were allowed to run at full capacity, but the results will be that the well will have a longer life and steadier flowage, and that ultimate recovery will be significantly increased. With reckless management, as much as 75 to 90 per cent of the petroleum in the underground strata may never be recovered, whereas with scientific management, whereby maximum gas pressure is maintained, recovery generally is well over 50 per cent, and in favorable circumstances it may be as high as 80 per cent.

Need for conservation of petroleum. Conservation of any natural resource implies its wise use, which of course carries also the thought that waste must be avoided. Insofar as the petroleum industry is concerned, such waste may be the result of recklessness, selfishness, or ignorance. In any event, there is a definite loss to society, and the public good suffers. That petroleum is an *irreplaceable* natural resource should always be kept in mind. The petroleum produced each year means that just so much less remains to be withdrawn. While it is statistically true that, in spite of heavy withdrawals during the war and postwar periods, the proved resources of petroleum had

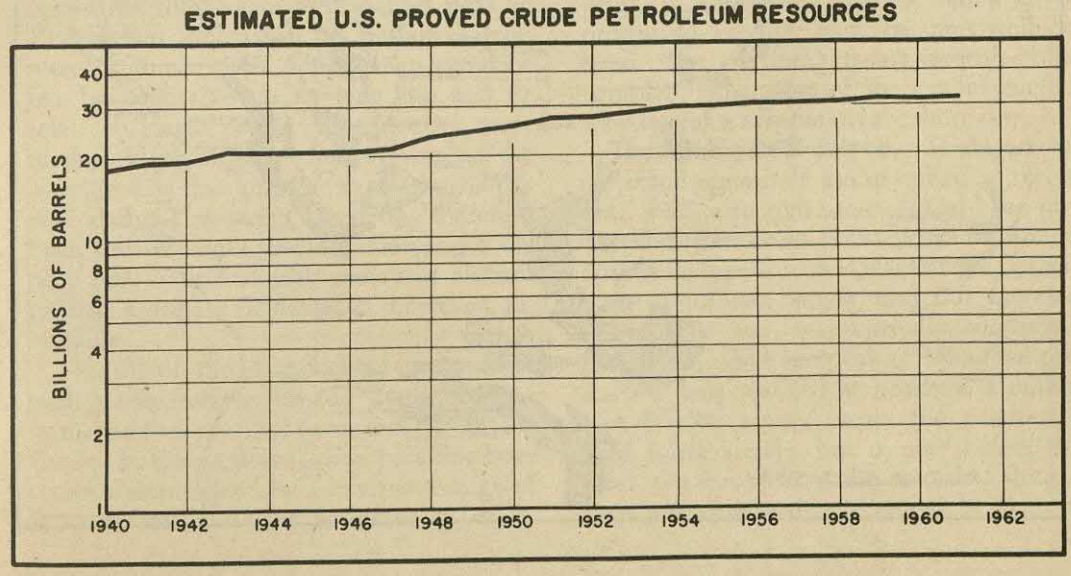
reached an all-time high in 1961 (Fig. 266), that does not imply that the actual reserves had increased; on the contrary, the actual reserves of this country were higher when Drake struck oil in 1859 than they have been ever since. Through exploratory drilling and improved techniques of production, knowledge concerning stores of petroleum available underground has increased, and thus estimates have expanded faster than production. As a result, the quantity of *proved reserves* still available has increased, although the *actual reserves* are becoming less with each passing day.

What, then, is the duty that confronts every intelligent citizen? It is, first of all, to recognize that petroleum prepared by Nature is a priceless resource, indispensable in the modern world in times of peace and war alike. Improved techniques of production will make higher ultimate recovery possible, but even so every pool, field, or province will eventually suffer decline and final exhaustion. Waste in any form hastens the day. The most serious form of waste now recognized is that of allowing gas to escape without being put to any use. This practice has been tolerated in the oil fields for an inexcusably long time, and even now such waste is all too prevalent in some fields. Fortunately, the importance of gas pressure as a factor in oil production is becoming more fully understood, and, consequently, control measures are becoming incorporated into the conservation laws of oil-producing states. Other phases of conservation in which all citizens should take interest include such matters as maintaining internal-combustion engines at high standards of efficiency and avoiding loss by leakage or evaporation in tanks or in transportation.

GEOGRAPHIC DISTRIBUTION OF PETROLEUM PRODUCTION IN NORTH AMERICA

Petroleum occurs in all three countries of North America, but by far the largest amount has been found in the United States. The geographic distribution of petroleum in North America can be studied most conveniently not by individual states or other administrative units, but by "provinces," i.e., larger areas of oil occurrence, in each of which certain common characteristics are found. These provinces are shown in Fig. 267. For the United States they will be treated in an east to west order, after which the Canadian and Mexican areas will be dis-

Figure 266.

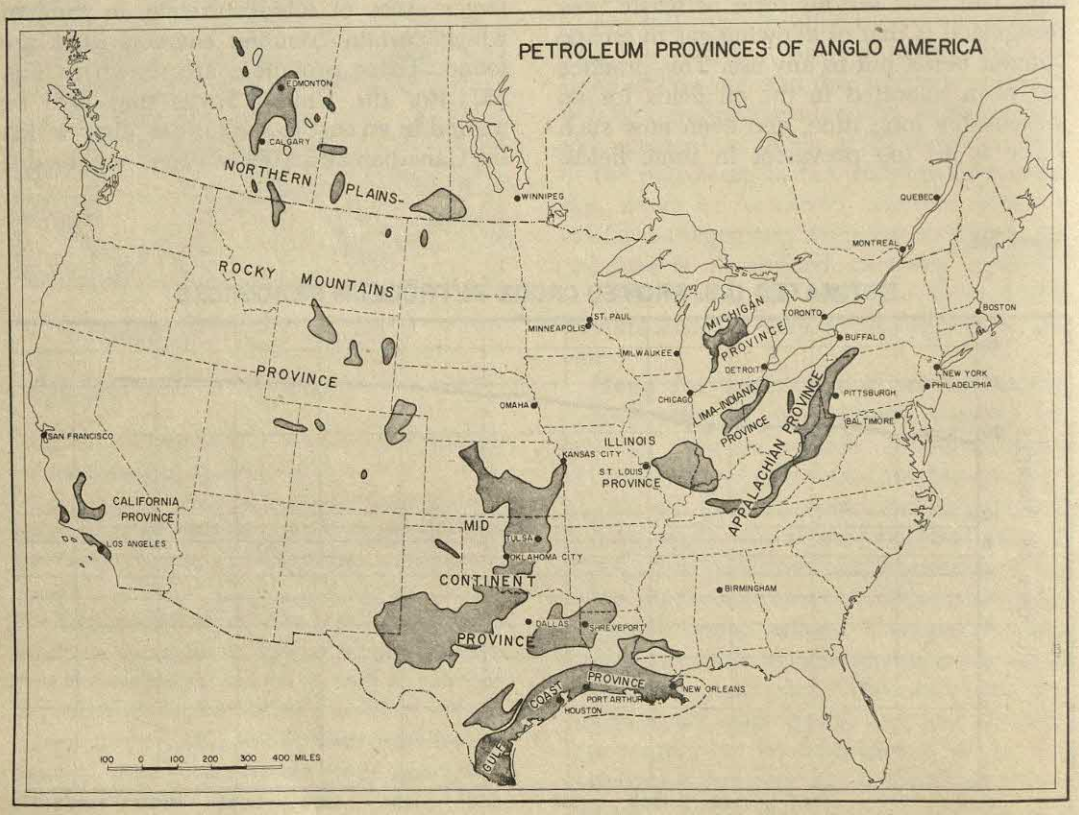


cussed briefly. Each province is composed of a large number of fields, most of which have names. Among the famous names are, for example, the East Texas field, noted as being by far the largest total producer in the United States; the Bradford-Allegheny field, the earliest producer of note; the Long Beach field near Los Angeles, another large producer; and many big but less well-known fields such as Sho-vel-tum, Oklahoma; Wilmington, California; Yates, Texas, etc. In each field there are few to many individual oil pools. Some of the petroleum provinces are so large that they are often further subdivided.

The Appalachian province. The first great oil field to develop on a large scale was the one that extends from southwestern New York through Pennsylvania and eastern Ohio and southward into Tennessee (Fig. 267). Oil had long been known to exist in seepages along some of the creeks of northwestern Pennsylvania, and for many years the crude had been skimmed from the surface of the waters and used by the Indians as an ointment and for medicinal purposes, a practice that was also taken up by white people when they came into that section of the country. In some places people who had tried to dig wells for water had penetrated oil-soaked muds and sands, but the knowledge of petroleum possibilities was then so slight that they considered themselves unfortunate because the oil had ruined their chances of obtaining good drinking water.

With the success of the well discovered by Drake in 1859 all this was changed, and a rush of drilling followed. The pioneer wells of 1859 and 1860 produced more oil than any one had ever seen before. At the end of 1860 there were altogether about 74 pro-

Figure 267.



ducing wells yielding about 1,200 barrels daily. The first great flowing well where oil came to the surface by itself, and did not have to be pumped up, was completed in September, 1861; it started with a production of 3,000 barrels a day and is often referred to as the first "gusher." Such results were wholly unexpected, and people were then willing to believe anything. The first oil boom was on, and the buying interest in proposed wells became a public craze. The boom, however, was of short duration because the market soon became flooded with oil, and the price dropped from over $20 per barrel to almost zero. Thousands of barrels are reported to have been sold at $.05 per barrel. Thus, within three years after the discovery well came into production, the young petroleum industry had experienced the thrill of boom conditions and the gloom of depression. Thereafter, however, the industry steadied, and for many years Pennsylvania furnished the major portion of the crude for an ever-growing American industry.

An early peak in production in the Appalachian province was reached in 1891, when more than 31 million barrels of oil were obtained. This was followed by a slow and persistent decline, but a revival of production through deeper drilling, improved methods of pumping, and the discovery of new pools in the southern part of the province raised the total again to a second peak in 1943, when more than 35 million barrels were produced. The Appalachian province has been notable for its long life and its relatively steady production. However, some of the older portions now produce, on the average, less than one fourth of a barrel per well daily. The recent trend has therefore been toward slight decline; one cannot say now how long that may remain a characteristic. Ultimate depletion is, however, inevitable.

The oil of the Appalachian province is high grade, ranging from 40° to 45° Baumé in the eastern portions to around 30° to 35° Baumé in the western. It is a paraffine-base crude characterized by a low percentage of residue, and it is free of sulfur, is easily refined, and is rich in the light constituents as well as in high-grade lubricating stock. These favorable properties cause the oil from this province to be ranked exceptionally high, and the term "Pennsylvania-grade" has come to stand as representative of the world's best oil. Because of its high quality and its nearness to the great marketing centers, it is the highest priced crude in the United States.

The Northeast Indiana-Ohio province. This province extends in a general southwesterly direction from near the west end of Lake Erie into eastern Indiana (Fig. 267). It lies on the west flank of the Cincinnati anticline, the crest of which separates it from the Appalachian province to the east. Production began in 1884, reached its maximum in Ohio in 1896, and in Indiana in 1904. Since then decline has been persistent, and no revival of production is likely. The oil is of paraffine base and is fairly light, averaging 30° to 35° Baumé. It is somewhat difficult to refine because of its sulfur content, but improved methods of refining have now largely overcome this difficulty. Notwithstanding the favorable location of the province and the relatively high quality of the oil, the crude usually sells considerably below that of the Appalachian fields.

The area has been quite thoroughly exploited, and, although commercial production is likely to continue for a number of years, it now seems that the limits of the producing acreage have become well defined. The declining trend indicates that complete exhaustion of the available oil is a matter of a comparatively short time.

The Michigan province. Michigan was not listed separately in the statistical record until 1925, although some oil had been produced earlier. From 1925 to 1929 the annual output increased from 4,000 barrels to more than 4½ million barrels, and this increase, sharp as it was, was virtually continuous until 1939, when the peak of Michigan production was reached at nearly 23½ million barrels. For several years the production held fairly steady, but is now below this level. On the basis of the record to date, it does not appear that Michigan is likely to

reach the large production that has characterized most of the major fields of the United States.

The Illinois-Southwest Indiana province. The petroleum-producing area of Illinois is mostly in the southern part of the state, the field extending into the adjacent portions of Indiana and Kentucky. Production began with 1,000 barrels in 1889 and expanded rapidly to 33 million barrels in 1910, after which there was a slow and steady decline to less than 5 million barrels in 1935. This was followed by discovery of new fields to the west and south of the old fields in Illinois, which caused a spectacular increase in production to more than 152 million barrels in 1940. Since that date, however, the output has dropped to around 90 million barrels.

The petroleum of Illinois is mostly of paraffine base, tests above 30° Baumé, is sulfur-free, and is easily refined. However, since the content of natural gasoline is relatively low (only about 15 to 20 per cent), the crude has a market value below what might be expected for oils of such low gravity.

The Mid-Continent province. The four provinces discussed thus far are comparatively small, and many of the fields within them have long ago reached the stage where production per well, though fairly steady, is low, and the oil must be pumped. Total production of all four provinces is less than half the current California production, considerably less than half of the production of the state of Louisiana, and not much more than the recent production of the state of Wyoming. The Mid-Continent province is newer, much more extensive than the provinces discussed previously, and by far dominates American production. In fact, it is at present one of the largest, most productive petroleum areas in the world. Included within the Mid-Continent province are the petroleum-producing fields which extend from near Kansas City southward across Kansas and Oklahoma into Texas and thence eastward across northern Louisiana and southern Arkansas into southern Mississippi and Alabama (Fig. 267). Comprising the western fringes of this vast area are the fields of central Kansas, the panhandle areas of Oklahoma and Texas, and the more recently discovered areas of western Texas, southeastern New Mexico, and southern Texas. Large-scale commercial development began about 1906. Since then, production has mounted steadily, year by year, and apparently the maximum output has not yet been reached (Fig. 268).

The Mid-Continent province produces practically all grades of oil: some have a paraffine base, some an asphalt base, and still others a mixed base. Some are almost as heavy as water, while others are as light and high grade as those of Pennsylvania. The complexity of structural conditions, different sources of origin, and the vast extent of the province are responsible for the pronounced diversity in the modes of occurrence and in the quality of the oils. The petroleums from the shallow wells south of Kansas City, for example, are heavy, of asphalt base, low in gasoline content, and of little lubricating value. On the other hand, those from the deeper sands at Augusta, Kansas, or Cushing, Oklahoma, are light, 35° to 40° Baumé, and contain a high percentage of natural gasoline and light lubricants. Such extremes of quality result in a wide range of prices for Mid-Continent petroleum.

The Mid-Continent province is noted for the wide diversity of capital interests represented. Since it was the meeting ground of east, west, north, and south, it was natural that capital from all of these sources should become interested in large-scale development there, and, as a result, more different companies are exploiting oil in this province than in any other area in the United States. These companies range all the way from those of world renown to those owned by a few people in some county or town. Contrary to popular opinion, no monopolistic condition prevails. Production, transportation, refining, and marketing are all on competitive bases, and the only semblance of any general agreement by these varied concerns is the movement toward limiting production to legitimate market demands. Even such agreements are subject to review by state conservation authorities and by the national government on the basis of agree-

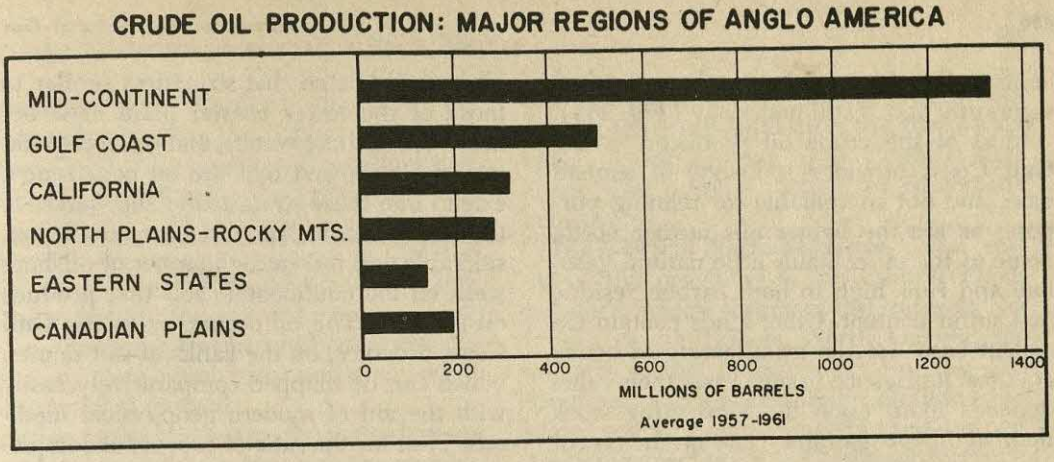
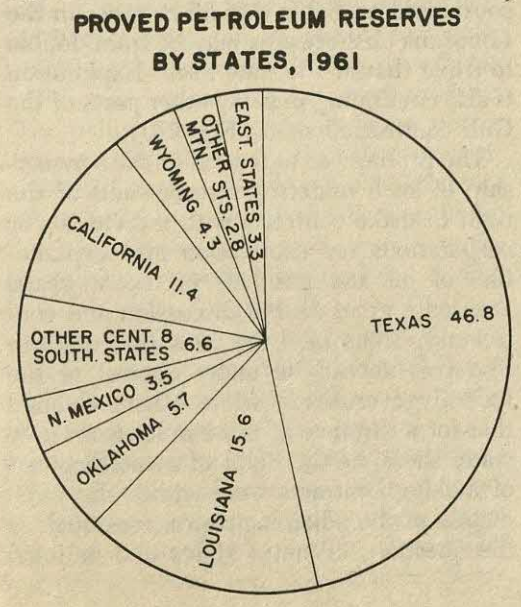


Figure 268.

ments voluntarily entered into by the parties concerned. Continued overproduction in the United States during a period of years led many to favor voluntary control of output as a conservation measure, whereas in earlier years any arbitrary curtailment of production would have raised loud protests in many sections. Recent developments have convinced people that production in proportion to a reasonable demand makes possible the highest prosperity for all and that long-sustained production at a rate greater than the market can absorb is unsound economic practice and wasteful of a great natural resource.

Figure 269.



While the potential production of the Mid-Continent province is enormous, the reserves are not inexhaustible. That the province will continue for some time to be the major producing area of the United States seems certain, but the actual amount in reserve necessarily decreases as exploitation increases. Oil production is a mining activity, and oil taken out is not replaced. In time, even the great Mid-Continent province must face declining output (Fig. 269).

The Gulf Coast province. The Gulf Coast province includes the producing fields of the area immediately along the coast of Texas, Louisiana, and eastward into southern Mississippi and southwestern Alabama. Formerly it was comparatively easy to separate the Gulf Coast province from the Mid-Continent province farther inland, but at present the two practically merge. Commercial production in this province began in 1901 and rose rapidly to its first peak in 1905, since which time declines and revivals have followed in almost rhythmical sequence, but there is good reason to believe that important output will continue for a long time (Fig. 267).

The oil occurs mostly in association with salt domes. The early discoveries were made by drilling on low domes which appeared as hills rising a few feet above the surrounding flat plain. In recent years production has been maintained through the discovery of buried domes not shown by the surface topography. Improved methods of geophysical prospecting have been quite successful in locating such structures, and therefore sci-

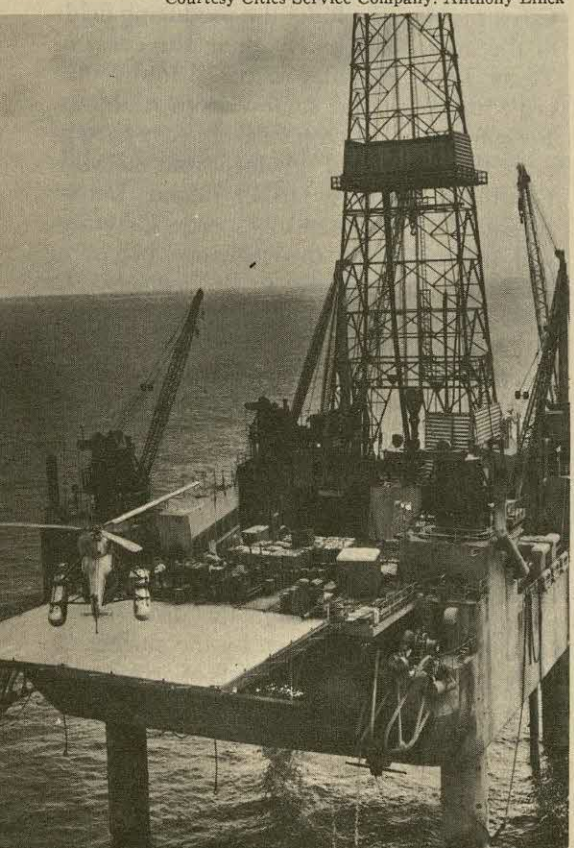
entific subsurface study has been pushed vigorously and is still underway (Fig. 263).

Most of the crude oil produced in the Gulf Coast province is heavy, of asphalt base, and not so valuable for refining purposes as are the lighter oils farther north. Some of the oil contains little natural gasoline and runs high in both carbon residue and sulfur content. Other kinds contain excellent bases for the manufacture of heavy cold-test lubricants; in such cases their value depends more upon the lubricating stock than upon the gasoline content. In recent years the improved methods of cracking heavy oils through distillation under high pressure have been important in giving value to such oils as sources of gasoline. On the whole, however, one of the chief uses of Gulf Coast petroleum is for marine fuels.

Exploratory work in the shallow waters offshore indicated that structures similar to those of the lower coastal plain exist beneath the offshore waters, and some exploratory wells showed that the oil occurrences extend into these strata under the waters of the Gulf. In Louisiana there are now a considerable and increasing number of offshore wells on the continental shelf that produce oil and gas. The oil occurs, as in the Gulf Coast province, on the flanks of salt domes, which can be mapped comparatively easily with the aid of modern geophysical methods. Thus far the ratio of successful completions to dry holes has been even more favorable than on the adjacent mainland. Oil is known to occur practically up to the edge of the continental shelf, which lies at a depth of about 600 feet and which, south of the town of Lake Charles, Louisiana, lies 130 miles from the shore. Exploration and drilling are continuing in this area, but as water depth increases, cost of drilling rises. In up to 60, and even 100, feet of water it has been possible to construct raised, fixed platforms for the operations. For greater depths new problems have to be met. However, newer and faster drilling techniques are used to overcome the higher cost of drilling in deep tidal water, and it has now also become possible to tap as many as six or seven producing horizons, one below the other, by the same well and simultaneously. This, of course, cuts costs greatly. It is now considered probable that oil reserves in the Louisiana offshore area may be from double to triple that of the state itself. Exploration is also continuing in many other parts of the Gulf continental shelf (Fig. 270).

Fig. 270. Enormous progress has been made in drilling methods, so that now even oil pools below the continental shelf can be tapped. This is an offshore drilling rig in the Gulf of Mexico. Note the helicopter and landing pad.

Courtesy Cities Service Company. Anthony Linck



The problem as to federal or state ownership of such undersea reserves and of the right to make contracts with individuals or corporations for exploration and exploitation of oil and gas has, in recent years, aroused a great deal of discussion and controversy. Some held the view that offshore resources should be under control of the federal government, while others claimed that for a distance of three miles from low-water shoreline the rights of ownership and of making contracts were within the jurisdiction of the adjoining states. Inasmuch as the questions of states' rights and national

sovereignty were involved, the case was finally submitted to the United States Supreme Court. The Supreme Court held that under the Constitution the federal government had full control of all oceanic waters below the low-tidewater line, and that the "high seas" would properly begin at a line 12 miles beyond the low-water line and not at 1 to 3 miles out as had hitherto been accepted by the United States and many other countries of the world.

Acting under this ruling, the United States Congress passed into law full concessions to the several oil and gas companies that they might explore for and exploit reserves of oil and gas in such areas and under such terms and royalties as seemed fair to the states, and that the states could assume full responsibility in the use of royalty funds for the public interest. Since the passage of the act in 1953, a large number of contracts have been signed, and a smaller number of wells have been completed, some as producers, others as "dry" holes. Until the major areas of the so-called tidelands have been developed, there is of course a possibility of change of policy by another act of Congress which would return control to the federal government, but the likelihood of such action diminishes with the passing of time. Should such action be taken, contracts already made would certainly remain valid. Much of the leasing has been for waters less than 60 feet deep, but in recent years geophysical exploration and drilling have been carried on in waters of much greater depth.

The policy regarding the undersea possibilities applies, of course, to all shorelines of the United States, whether Gulf, Atlantic, or Pacific. In the case of the Pacific, large oil reserves were discovered several years ago, and active production has been taking place on a rather large scale.

The problems of property rights to underwater oil and gas resources and, to a lesser extent, some recent fishery problems appear to have resulted in a general unsettlement of international law as pertaining to territorial waters. Claims for belts of varying widths have been made by many countries, some extending several hundred miles from the coastline. Also, there is little agreement among nations as to what legally constitutes the continental shelf, the area within which oil and gas may occur. Conflicts have arisen and become matters of diplomatic controversy.

The Central Plains province. The newest of the provinces is the Central Plains province, which embraces the states of Nebraska, South Dakota, North Dakota, the adjacent plains portions of Wyoming and Montana, and northeastern Colorado. The plains south of approximately the 40th parallel are part of the Mid-Continent province. To the north the Central Plains province merges with the Canadian or Northern Plains province. During the last two decades production in this area has increased greatly, Montana, Nebraska, and North Dakota being the chief producers, and in recent years the production of the province has been about double that of the Appalachian province. On the basis of evidence available at present it does not seem likely that the new province will become a counterpart to the Mid-Continent province to the south, although an appreciable increase in production may be anticipated. In much of the area oil traps lie deep and are therefore not readily discovered. Wild catting leads to many failures, but the rewards of the successful are high.

The Rocky Mountain province. The Rocky Mountain province is a convenient geographical designation for the area of mountains and basins which extends from the Canadian border in Montana through Wyoming, Utah, and Colorado into northwestern New Mexico. It includes many types of structure, and various kinds and qualities of petroleum are found in the area. The most important producing state is Wyoming, which is responsible for about half of the total production. The other half is fairly evenly distributed over the other states, with the Rocky Mountain section of New Mexico being the smallest producer. Most of the oil produced in the latter state comes from the southeastern portion of it, which belongs to the Mid-Continent province.

During the decade of the 1930's the province was characterized by declining production, and it looked as though the opti-

mism of earlier investigators was unfounded. However, further exploratory work met with a high degree of success, with the result that the total production of the province more than doubled during the period 1940-50 and again during the following decade. Thus the future outlook is one of considerable promise.

The California province. The California province consists of two major divisions, the older one, from the viewpoint of initial development, being the southern part of the San Joaquin Valley, and the younger one, the coastal area from Monterey County, about a hundred miles south of San Francisco, to a short distance beyond Los Angeles (Fig. 267). Because of seepages found in various places and the presence of asphalt in rock exposures, the existence of oil in both areas was known for many years prior to exploitation. It is claimed that asphalt, the "brea" of the Spanish settlers, was mined in Ventura early in the nineteenth century and that oil refined by simple distillation was prepared from seepages near Santa Barbara as early as 1857. Wells were drilled for oil in 1884, and the first successful wells in the San Joaquin Valley were completed at McKittrick in 1887. Inasmuch as local demands were small and eastern markets were remote, development was also slow until about 1900. Then, large-scale production began in the upper portion of the San Joaquin Valley, and from 1903 to 1915 California held the lead among the states in petroleum output.

The oil pools of California are characterized by high gas-pressure, which results in heavy flush output of wells unless efficient methods of control are put to use. The quality of the oil varies from light to heavy in different pools; some is of exceptionally high quality, but, for the province as a whole, mixed and asphaltic oils predominate. In spite of low prices for such oils, the early, great flush production made wells highly profitable and led to veritable orgies of drilling. Enormous production was obtained from several pools in the Los Angeles basin, which in proportion to its area must be classified as one of the most productive districts in the world. Among the nine United States fields that had produced *in toto* over 500 million barrels each by 1960, 6 were located in California. Competition for the oil caused too close drilling and resulted in production so rapid that markets for a time were unable to absorb the output. It probably also resulted in considerable waste of this national resource, since unwise dissipation of gas pressure must have left millions of barrels of crude oil forever unrecoverable (Fig. 271).

It finally became possible to convince oil



Fig. 271. The famous Signal Hill, California, oil pool, photographed in 1941. The forest of derricks, spaced much too closely for good conservation practices, resulted from the fact that this development took place in the suburbs of Los Angeles, where land was held in small lots, and from the absence of suitable regulation of exploitation.

Courtesy Standard Oil Company (California)

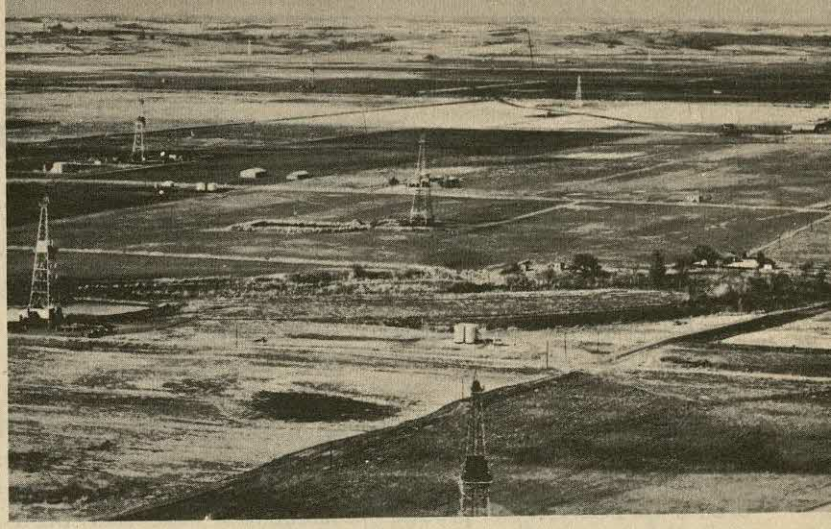


Fig. 272. Due partly to the work of scientists, partly to the Great Depression of the thirties, much progress has been made in the methods of exploiting oil pools. Today, wells are spaced with an eye to maintaining underground pressures and flow is carefully regulated, so that a maximum of crude oil can be extracted.

Courtesy Standard Oil Company (New York)

interests of what scientists had known for a long time, namely that unrestricted drilling is uneconomical, not only because it entails waste of capital expended on unnecessary wells, but also because the rapid reduction of gas pressure lessens the amount of oil which can ultimately be obtained. California was able to enact a state conservation law to prevent the waste of natural gas and thereby to not only conserve the gas for domestic and industrial use but, through maintained gas pressure, to increase the amount of petroleum which can ultimately be recovered from the producing sands. Such forward-looking legislation is highly commendable because it reflects the same view that wanton waste in utilizing natural resources is economically unsound, and that immediate profits of a few must give way before the greater ultimate good to the many. Conservation laws and regulations are now in force in many states (Fig. 272).

High production of petroleum in California seems probable for a number of years, notwithstanding a tendency toward decline evident in recent years. Reserves are great, and it seems highly probable that additional producing areas will be discovered. About 5 per cent of the production is from offshore wells.

The Canadian or Northern Plains province. The vast plains that begin in Texas stretch far north into Canada, between the Canadian Shield to the east and the Rocky Mountains to the west, reaching the Arctic Ocean at the delta of the Mackenzie river. Exploration for oil has been carried out for many decades, and oil was first discovered in 1913 in the Turner Valley field near Calgary. Production, however, remained comparatively small until the discovery in 1947 of the Leduc-Woodbend field, south and west of Edmonton. At present almost all of the oil and gas produced in Canada come from this province, Ontario and New Brunswick contributing only a small fraction—less than 1 per cent—to the total (Fig. 267).

The largest production of oil and also the largest reserves are in Alberta Province, from the United States border to beyond Edmonton and from there northwestward toward Dawson Creek in British Columbia. Extensive gas fields have also been discovered in this area. British Columbia production is in the Peace river area, east of the Rockies. Other important areas are southwestern Saskatchewan and the southeastern Saskatchewan-southwestern Manitoba area. Total Canadian production of crude oil is somewhat over one fifth of Texas production.

The known reserves of petroleum in Canada were estimated in 1960 at nearly 3,700 million barrels, a supply large enough to provide for the needs of the country for many decades.

The Mexican Gulf Coast province. The oil fields of Mexico are a continuation of the fields of the Gulf Coast province of the United States, but the mode of occurrence is not limited to that in salt domes. Producing areas lie near the coast from the Rio Grande river to southwestern Campeche,

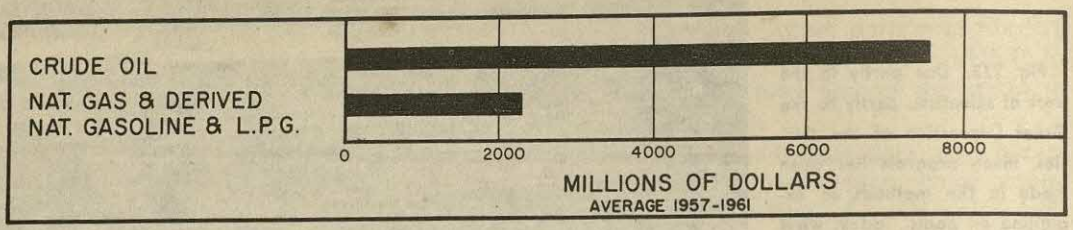


Fig. 273. Comparative value of extracted crude oil and natural gas.

with major production between Tampico and Veracruz and in Tabasco. Although lighter oils occur in the area, many of the crudes are heavy. Total production is about equivalent to that of the state of New Mexico in the United States.

Also, in Mexico there is offshore oil, and producing wells occur, for example, off the Tabasco coast. Proved reserves of Mexico are substantial, and may be enlarged considerably by further offshore discoveries.

Gas fields of North America. While in the preceding pages the emphasis has been upon the production of oil, hydrocarbons in gas form usually occur with the crude. Thus, in a general way, the two occur in the same areas. However, within those general areas there are many fields that produce only natural gas (Fig. 274).

COMMERCIAL DISTRIBUTION OF PETROLEUM PRODUCTS IN NORTH AMERICA

Transportation and storage of oil and gas. When production of petroleum in large quantities began, the producers were immediately confronted with the problem of its transportation. Petroleum was then a new type of commodity: the railroads were not equipped for the efficient handling of liquid freight. Haulage at first was in barrels, a method that proved inadequate from the outset. This led to mounting tanks on railroad trucks, and thus was initiated tank-car shipment of crude oil to refineries.

The flush production of some of the pools so greatly exceeded even the most hopeful expectations that tank cars with which to handle it were not available. In short, the freight-car type of transportation for crude oil was not flexible enough for the oil industry, a fact which became obvious within a few years after the discovery well at Titusville had been brought into production. Nevertheless, tank-car shipments by rail have continued to be of importance in the oil industry throughout much of its history. At present, however, railroads carry less than 3 per cent of all crude petroleum and products transported in the United States, somewhat less than half being transported by pipeline and about one quarter each by water carriers and trucks.

PIPELINES. Transportation of crude oil through pipelines was an outgrowth of the method used successfully by water systems. This method of moving oil was first used about 1865 in Pennsylvania, where the practice began with wooden pipes, which were soon replaced by pipes of iron and steel. It now has grown to such magnitude that many sections of the United States are served by a veritable network of pipelines (Fig. 275). This is the most efficient and least costly form of overland freight haulage that has yet been devised. The total mileage of pipelines for transporting petroleum, refined products, and natural gas is reported to have reached the astounding figure of over 800,000 miles. The term "pipeline" now implies a complete transportation system, including trunk lines, gathering lines, initial and terminal storage systems, commercial lines, and power plants. These are all handled under one management.

Steel pipes of 12 to 30 inches in diameter are used for most of the trunk lines, while those of smaller diameters are used for the gathering lines and some of the main lines. The oil is moved by means of pumping stations which serve as boosters or pushers to force the petroleum from one station to the

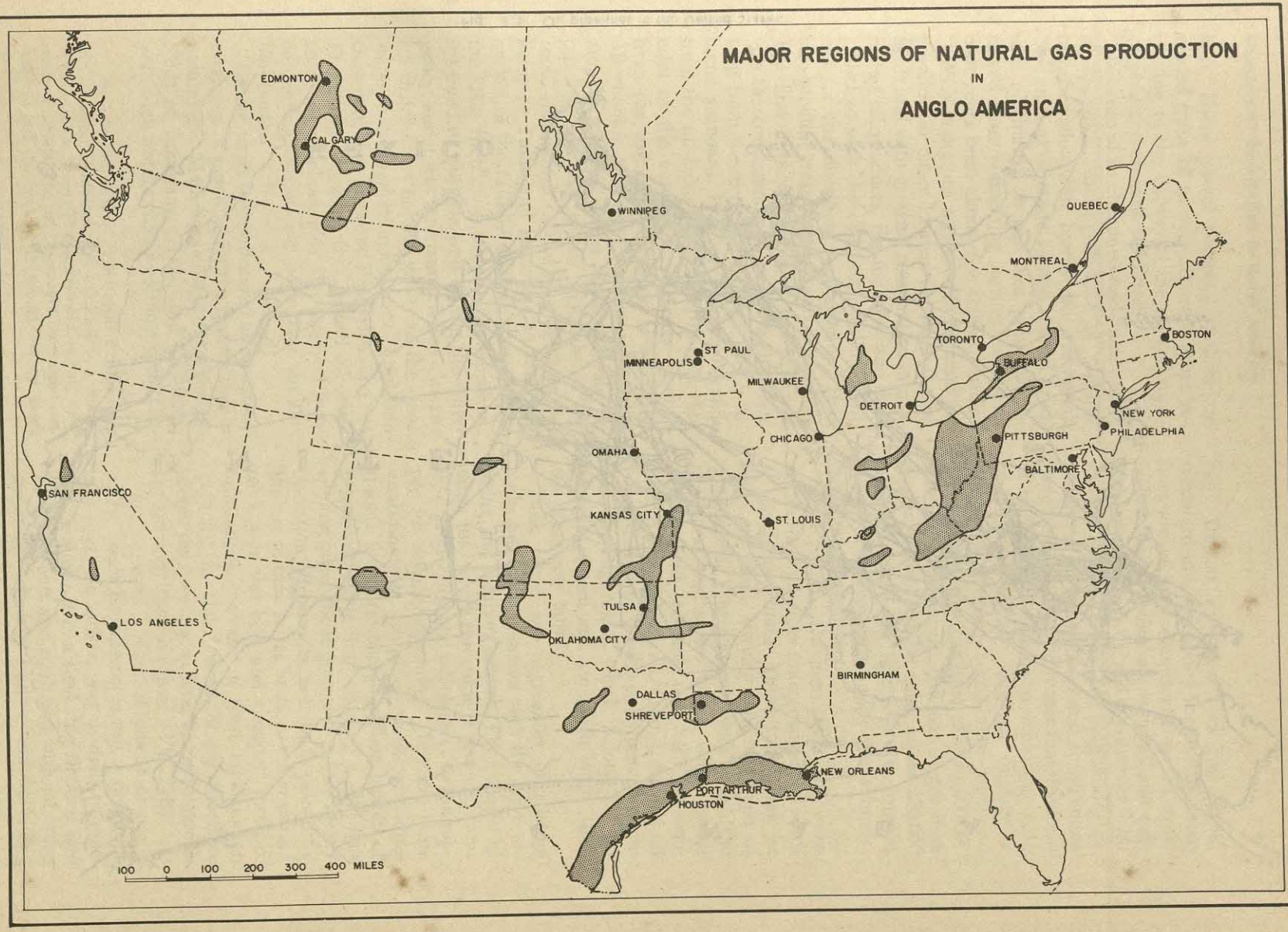

MAJOR REGIONS OF NATURAL GAS PRODUCTION
IN
ANGLO AMERICA
EDMONTON
CALGARY
WINNIPEG
QUEBEC
MONTREAL
TORONTO
BOSTON
BUFFALO
ST PAUL
MINNEAPOLIS
MILWAUKEE
DETROIT
NEW YORK
PHILADELPHIA
CHICAGO
PITTSBURGH
BALTIMORE
OMAHA
SAN FRANCISCO
KANSAS CITY
ST LOUIS
TULSA
LOS ANGELES
OKLAHOMA CITY
BIRMINGHAM
DALLAS
SHREVEPORT
NEW ORLEANS
PORT ARTHUR
HOUSTON
100 0 100 200 300 400 MILES

Figure 274.



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Fig. 275. Oil pipelines in the United States.

next. These power pumping stations are spaced from 12 to over 50 miles apart according to the density of the oil and topographic and climatic conditions.

Because of its cheapness and its flexibility of operation, the significance of pipeline transportation can hardly be overstated. The amount of crude oil and refined products originated on pipelines plus that received from connecting carriers has in recent years been almost five billion barrels.[2]

With enormous increases in demand for gasoline in cities located far from the oil fields and with growing competition in marketing oil products, the industry was compelled to seek the cheapest possible methods for the distribution of gasoline. Here also pipeline transportation was the answer. The first important shift in this direction was the conversion of a large pipeline running from western Pennsylvania to the Atlantic seaboard. Formerly it carried crude from the oil fields of the west to the refineries of the east. Now it carries gasoline from the east to the markets west of the Alleghenies. The most striking example of moving gasoline on an immense scale by pipeline was that of the well-known "Big Inch" line, which carried gasoline from the fields of Texas and Louisiana to seaboard outlets of the Middle Atlantic coast. While the "Big Inch" was a war-time expedient, it served its purpose well during the emergency, and it was later converted to a means for distributing natural gas from the same states to the markets in the great population centers of New York and Pennsylvania. (See Fig. 275). The amount of refined oil originated on pipelines plus that received from connecting carriers has been over one billion barrels.

Recent years have witnessed an enormous extension of pipelines for the distribution of natural gas. Main lines now connect the gas fields of Louisiana, Texas, and Oklahoma with such distant cities as Minneapolis, Chicago, Detroit, and New York and extend westward to Los Angeles. Some of the main lines are of huge diameter, from 18 to 30 inches. To lay these lines over hill and dale and across large rivers and to construct them leakproof is a job of the first magnitude, but problems of manufacture and construction have been so successfully met that this form of transportation has been expanding with phenomenal rapidity. The total mileage of pipeline for the transportation of crude and refined petroleum has been close to 200,000 miles in recent years, but that of gas lines has been over 600,000 miles, about 250,000 of the latter being field and transmission lines and the remainder utility mains for distribution to customers.

TANK FARMS. Oil from producing wells is run through pipes into receptacles known as *producers' tanks*. These tanks may be large or small, varying with the type of production. Where strong wells occur, the producers' tanks are large; where small wells prevail, the tanks may hold not more than 200 to 500 barrels. From these the oil is transferred by gravity or by pumping into the *working tanks*, which belong to the pipeline system and are much larger than the producers' tanks.

Tank farms are aggregates of storage tanks built in connection with the large refining and shipping centers. They consist of tanks into which the crude is received from field production and which serve as the supply for refinery operation. They are large establishments, some of them providing storage for more than 10 million barrels of petroleum. Aside from carrying a sufficient amount of oil above ground to assure steady operation of refineries, nothing is gained by the use of tank farms because underground storage is the best and cheapest method. Substantial increase in total tank-storage capacity in the United States therefore seems unnecessary as long as petroleum is the principal fuel involved (Fig. 276).

OIL TANKERS. When shipment of crude oil by water became necessary, a new type of vessel, the tanker, was devised to meet the demand. It is a steel ship divided into compartments and equipped with pumping apparatus whereby loading and unloading

[2] An American billion is 1,000 million. Elsewhere this is called a milliard, and a billion is a million to the second power. The figure includes only companies that report to the Interstate Commerce Commission, but the real figure would not be much larger.



Fig. 276. Baton Rouge, Louisiana, tank farm and refinery from the air. Mississippi river loading dock in foreground, large refinery in center of photograph, with tank farms at right and left.

Courtesy Standard Oil Company of New Jersey

may be quickly accomplished. With the development of extensive international trade in petroleum, tanker tonnage has had almost phenomenal growth (Fig. 277).

Tankers plying between Caribbean ports and New York City have capacities of 80,000 to 150,000 barrels of crude. In general, smaller boats ply between Mississippi and Gulf ports of the United States, whereas much larger ones operate in the transatlantic service. The sturdiness and efficiency of these ships make the importation of petroleum from South America and the Near East to American refineries economically practical in competition with domestic production. Of even greater significance is the assurance they give of adequate, dependable supplies from South America and from overseas sources to supplement the domestic production as need may develop. About one seventh of the tonnage of the world's tank-ship fleet is under American flag, and over half is under European flags. By volume, oil accounts for about 48 per cent of total sea-borne trade (by value, for about 9 per cent).

STORAGE OF NATURAL GAS. In middle-latitude climates the natural-gas industry faces the problem of great variation in demand during the year due to seasonal temperature differences and the fact that a large percentage of the gas is used for space heating by small consumers. To offset these extremes in demand, the natural-gas companies make contracts with large consumers, such as manufacturing and industrial concerns, for the sale of gas at lower rates but with the proviso that, when necessary, their supply will be curtailed or reduced. On the other hand, the small businesses and individual householders are given so-called *firm* contracts which give assurance of supply at all times but at somewhat higher rates. Even so it is necessary, as well as economically wise, to have gas in storage to meet peak demand during the cold season. For this purpose, caves, abandoned mines, old salt mines, and similar structures are being put to good use for underground storage of gas at low cost.

PETROLEUM IN OTHER AREAS OF THE WORLD

Since 1859 the United States has produced approximately 65 per cent of the world supply of petroleum; at the present time it produces about one third. Other countries which rank high in production are Venezuela, the Soviet Union, Iran, Iraq, Saudi Arabia, and Kuwait (Fig. 278). The proved reserves of oil and gas of the various continents and parts of continents are far from equal. On the basis of present evi-

dence the Near East (the area from Iran to Egypt and from Yemen to Turkey, also sometimes erroneously referred to as the Middle East) has by far the largest proved reserves of crude oil, probably between five and six times those of the United States. The North American continent is next, with the bulk of the reserves in the United States. This is followed by Eastern Europe and adjacent Asia, from East Germany, Czechoslovakia, Hungary, Yugoslavia, and Albania to easternmost Russia. South America stands fourth, followed by southern and eastern Asia (including Indonesia), Africa, Western Europe, and Oceania.

ESTIMATED CRUDE-OIL RESERVES OF THE WORLD IN BILLIONS OF BARRELS (1962)

Near East	192
North America and West Indies	39
Eastern Europe (incl. USSR)	24
South America	21
Far East	10
Africa	13
Western Europe	1½
Oceania	small

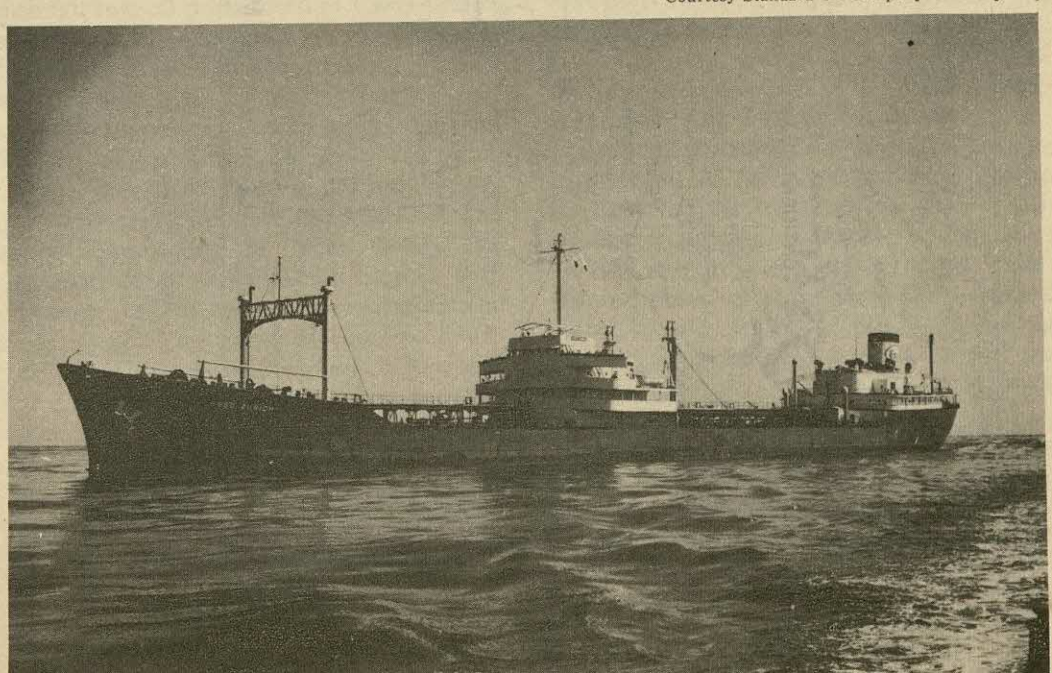
SOURCE: *World Oil*, Vol. 157, No. 3, p. 65, August 15, 1963.

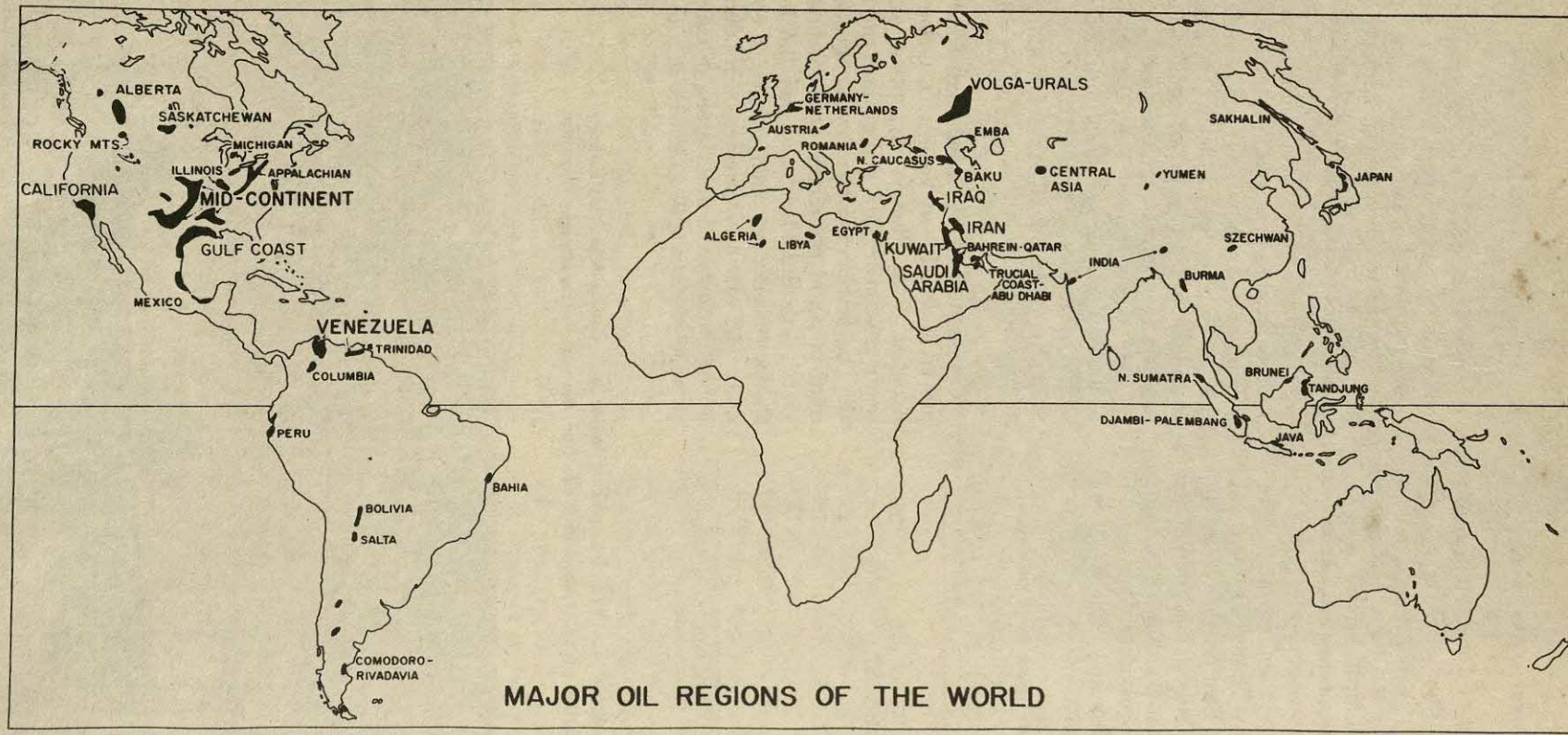
South America. In South America the best undeveloped prospects appear to be the upper parts of the plains east of the Andes from Argentina to Venezuela. Exploration in the part of the Amazon Interior Plains that lies within Brazil thus far has been discouraging. The Guiana Shield to the north cannot be expected to harbor any petroleum, and chances are equally unfavorable in eastern Brazil, much of which is crystalline upland, with in many places a comparatively thin and unfavorable cover of sedimentary rocks. The vast stretches of the Andes are so severely distorted that within the mountain area oil can occur only in scattered basins. (See the continental map of South America which precedes the text.)

Commercial exploitation has thus far proved successful in Venezuela, Colombia, Ecuador, Peru, Bolivia, Argentina, and a small area near Salvador or Baía in Brazil. The first-named has ranked second or third in world production for a number of years, with the Maracaibo and the lower Orinoco basins the chief centers of operations. The extent of commercial production in both basins indicates a strong probability of large reserves still to be developed into

Fig. 277. Supertanker Esso Zurich waiting to pick up harbor pilot outside New York harbor. Large tankers serve to bring added supplies of crude from overseas to supplement domestic production.

Courtesy Standard Oil Company of New Jersey





MAJOR OIL REGIONS OF THE WORLD

Figure 278.

production (Fig. 278). For the entire country the annual output has reached over one billion barrels, and the rising trend promises to continue for some time. Venezuela may therefore be expected to retain her position as one of the leading petroleum countries of the world.

Peru first appeared on the records as an oil producer in 1896, but did not reach the million-barrel-per-year figure until 1909. Recently the annual production has ranged from 7 to 20 million barrels. The fields are in the northwestern part of the country along the Pacific coast, south of the Gulf of Guayaquil, and near the Ucayali river east of the Andes.

Production in southwestern Ecuador, on the north side of the Gulf of Guayaquil, has continued moderately successfully for many years; output there first exceeded a million barrels in 1928 and since then has remained comparatively steady at from two to three million barrels per year.

In Colombia the principal producing fields are on the low western flanks of the Cordillera Oriental, one of the major ranges of the Andes, about 425 miles inland east of the Magdalena river, and on the eastern flanks of the Sierra de Perija in valleys that drain into Lake Maracaibo. This production is piped westward across the Andes, where it meets, but does not join with, production from the earlier fields for export through two oil ports south of Cartagena to overseas markets. Since 1940 the output of petroleum in Colombia has ranged from 12 to 56 million barrels per year, but the possible production appears to be greater than that actually attained.

Argentina has had slow but steady growth in petroleum output since 1913. The annual production in recent years has ranged from 30 to 98 million barrels, with prospects of further increase during the years ahead. The principal centers of output are the Comodoro Rivadavia field, about 900 miles south of Buenos Aires, and the newer fields east of the Andes in southernmost, central and northern Argentina (see Fig. 278). These fields continue northward into Bolivia, and perhaps even farther north, with extensions still to be determined. In Bolivia exploitation is underway. The fields now in active exploitation are located immediately east of the Andes in the area from Santa Cruz southward to the above-mentioned fields in northern Argentina. Pipelines have been constructed to La Paz and to the port of Arica in northern Chile.

Chile was the scene of considerable exploration for a number of years, but results were negative until 1949, when petroleum was discovered in Tierra del Fuego. Successful exploitation in that southernmost part of South America has been attained, the producing area extending into the eastern part of the island, which is Argentinian territory.

The potentialities of South America have not been completely explored, and therefore knowledge concerning possibilities is still incomplete. Much exploration is continuing all along the east foot of the Andes mountains, in practically all of the countries concerned.

Western Europe. The rock structures of southern and western Europe are so broken and disturbed that it does not seem probable that any really extensive petroliferous areas will be discovered. Comparatively small fields are located in such widely scattered places as the Aquitaine basin, the Paris basin, and Alsace in France; in several sections of the Netherlands; in several parts of West Germany, especially the Hanover, Emsland and Weser-Ems regions; in Sicily, Italy, and in Austria. Production has also been attained in the United Kingdom, mostly in the East Midlands.

Eastern Europe. In Eastern Europe, in addition to the Caucasus area, Russia is characterized by extensive plains with structures similar to those which have yielded much oil in interior United States. Beyond the Ural Mountains, plains extend eastward to the Yenisei river and southward to the Iran-Afghanistan border; beyond the Yenisei there are also some favorable areas.

The Soviet Union and Romania lead all other European countries in output, the former by a wide margin. Romania has been producing petroleum for more than 90 years, though during most of that time the produc-

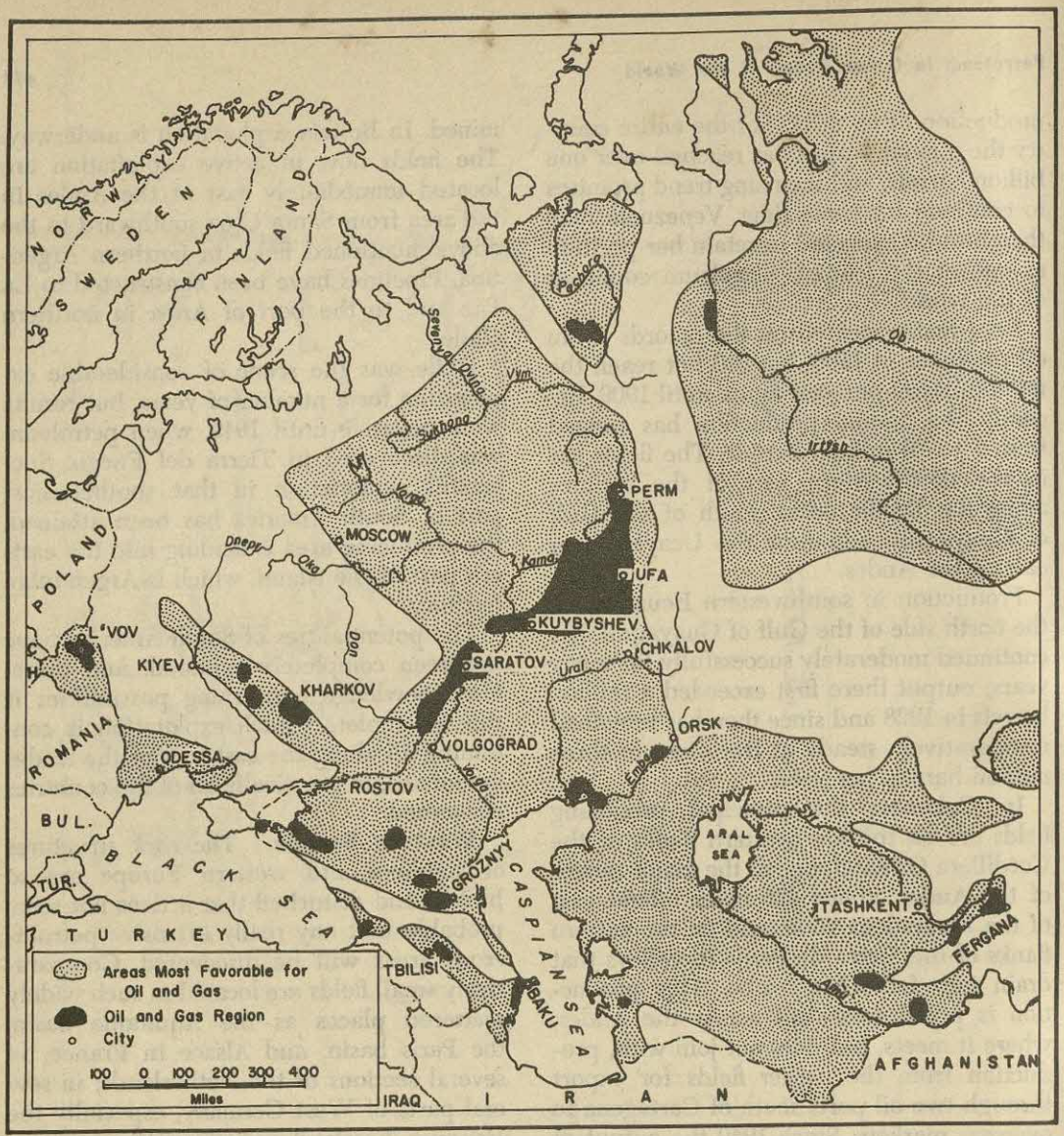


Fig. 279. Oil and gas regions in western USSR.

tion was comparatively small. However, the output gradually increased, reaching 35 million barrels in 1929 and 63 million in 1936. In recent years production has been between 80 and 90 million barrels.

Russia produced petroleum long before 1860, from shallow hand-dug pits, and has consistently been one of the leading nations, usually ranking second. For several years in the early part of the present century, Russia ranked first, surpassing the United States, and for many years the principal producer was the famous Baku field on the Apsheron peninsula at the Caspian Sea end of the Caucasus Mountains. Later a number of other fields came into production on both sides of the Caucasus Mountains, such as the Upper Kura river field to the south and the Maykop-Krasnodar, Budennovsk, and Groznyy-Makhach Kala fields to the north. To the north and northeast of the Caspian Sea oil was discovered in the Emba salt-dome area. All of these fields still produce. In fact, in the Baku area, now largely a region of small wells, significant offshore deposits have been discovered (Fig. 279).

At present, however, all these older fields

have been reduced to comparative insignificance by the discovery of a huge oil and gas area referred to as the Urals-Volga region. The ultimate extent and shape of this area is still not known, but at present it reaches from Perm (formerly Molotov) in the north nearly to Chkalov (Orenburg) in the south, and from there westward to and beyond the Kama river and southwestward to Kuybyshev on the great bend of the Volga. From there it more or less follows the Volga downstream, lies mostly to the west, but partly to the east of the river, and nearly as far south as Volgograd (Stalingrad). Between 70 and 80 per cent of the country's production now comes from this area. There are other, smaller fields in the western Ukraine; across the Caspian Sea from Baku; in the Fergana basin; in northern Sakhalin; and in a few other places. Much exploration, however, remains to be done, and large areas in European and Asiatic Russia are favorable for oil. Long pipelines have been constructed, especially from the new Urals-Volga region: southward to the Caspian; westward to Poland, Czechoslovakia, the Baltic coast, and the Black Sea coast; and eastward to Omsk in Siberia and beyond. Many others are under construction or in the planning stage. Production in the Soviet Union may be expected to increase for years to come, and the country will continue to rank as one of the three or four largest producers of petroleum in the world. In recent years production has ranged between 1,200 and 1,400 million barrels.

Near East. As mentioned above, on the basis of present knowledge the Near East has by far the largest oil reserves in the world, and as a producing area it rivals the United States. Production is divided, however, over a number of political units, among which Kuwait, Saudi Arabia, Iran, and Iraq are the outstanding producers (Fig. 280).

Iran. The producing areas in Iran are located mostly in the low, southwestern portion of the country west of the mountains and north of the head of the Persian Gulf. The crude is transported by pipeline to refining facilities constructed at Abadan, below Basra, and to Kharg Island (Khor-al-Amaya terminal) in the Persian Gulf. From there the products are shipped by water routes to markets of Asia and Europe. In American statistics Iran (then Persia) first appeared as an oil producer in 1913, credited with an output of 1,857,000 barrels. At first progress was slow, but after 1920 production increased rapidly, reaching a peak in 1952 of 242 million barrels. Political problems caused unsettled conditions, and the great refinery at Abadan (then the world's largest) was closed, and production curtailed. Negotiations in late 1953 led to resumption of operations on a reduced scale. In recent years production has been between 400 and 500 million barrels. If political stability continues, the outlook is for long-continued prosperity of the petroleum industry of Iran because the reserves are known to be abundant.

Iraq. The oil fields of Iraq are located near Kirkuk in northern Iraq and in the extreme south, near Basra (Fig. 280). Although strong wells were struck in the north a number of years ago, commercial production there was delayed because of lack of transportation facilities. A 1,150-mile pipeline of 12-inch diameter with a daily capacity of 85,000 barrels was begun in 1932 and completed for active service in 1935. It runs from Kirkuk to Haditha on the Euphrates and from there to Tripoli, Lebanon, and Baniyas, Syria, on the Mediterranean coast. Iraq has grown to be a prominent oil-producing country. In recent years its production has been between 300 and 400 million barrels, and an upward trend appears likely to continue for some time.

Arabia. In recent years American and other interests have undertaken extensive exploratory investigations in the vast territory commonly designated as Arabia (Fig. 280). This territory includes the governmental units known as Saudi Arabia, Kuwait, Bahrain, Qatar, the Neutral Zone, and Abu Dhabi-Trucial Coast (Trucial Oman). Strong wells have been discovered, and many are in active production. Although under different sovereignties, the producing area is really one unit from the physical point of view, reaching from the Iranian

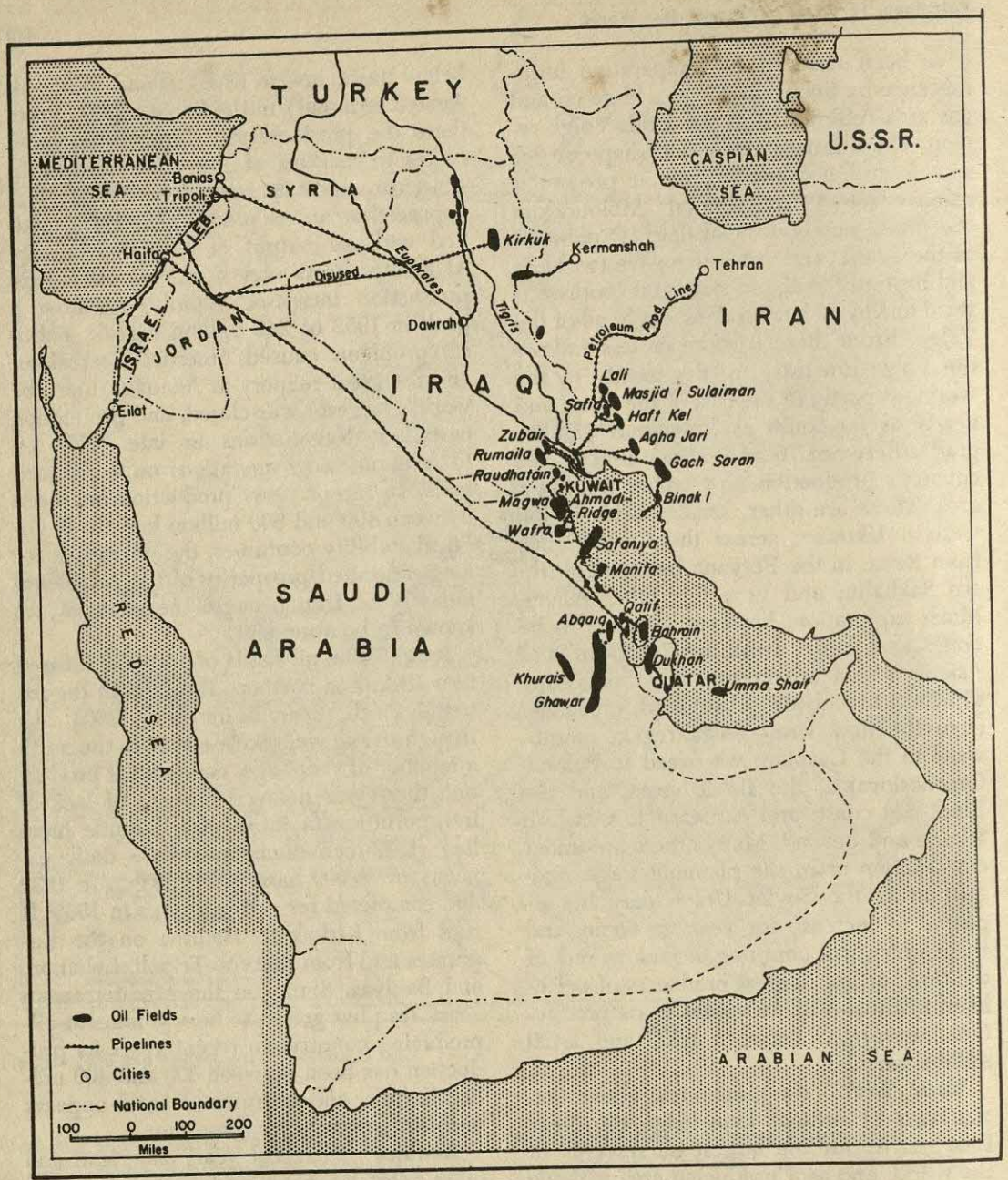


Fig. 280. Oil fields and pipelines of the Near East.

and southern Iraq fields around the head of the Persian Gulf through Kuwait, the Neutral Zone, Saudi Arabia, Bahrain, and Qatar to Trucial Oman. The production of Kuwait has been around 600 million barrels; Saudi Arabia, between 500 and 600; Bahrain, between 10 and 20; and Qatar, between 60 and 70. A great deal of offshore exploration has been carried on in the shallow Persian Gulf, which is a continuation of the Mesopotamian Plain, and several major offshore fields have already been discovered.

The entire land and water area from Mosul in the north to the Strait of Hormuz in the south is apparently the major oil region of the entire world. Production elsewhere in the Near East is insignificant thus far.

Southern and eastern Asia. Oil is produced in a number of countries of southern and eastern Asia, but the only producers of note to date are Indonesia and northern Borneo.

Indonesia, formerly the Netherlands East Indies, became an important oil producer in the 1890's and has remained so since. In 1939 the output was approximately 60 million barrels, but in succeeding years production was much less because of the effects of war and postwar disruption. In 1948 recovery had set in, and 32 million barrels were produced. The upward trend has continued, and in recent years production has been around 160 million barrels. The fields are in southern Sumatra, northern Sumatra, eastern Java, and southern and eastern Borneo, the island called Kalimantan by Indonesians.

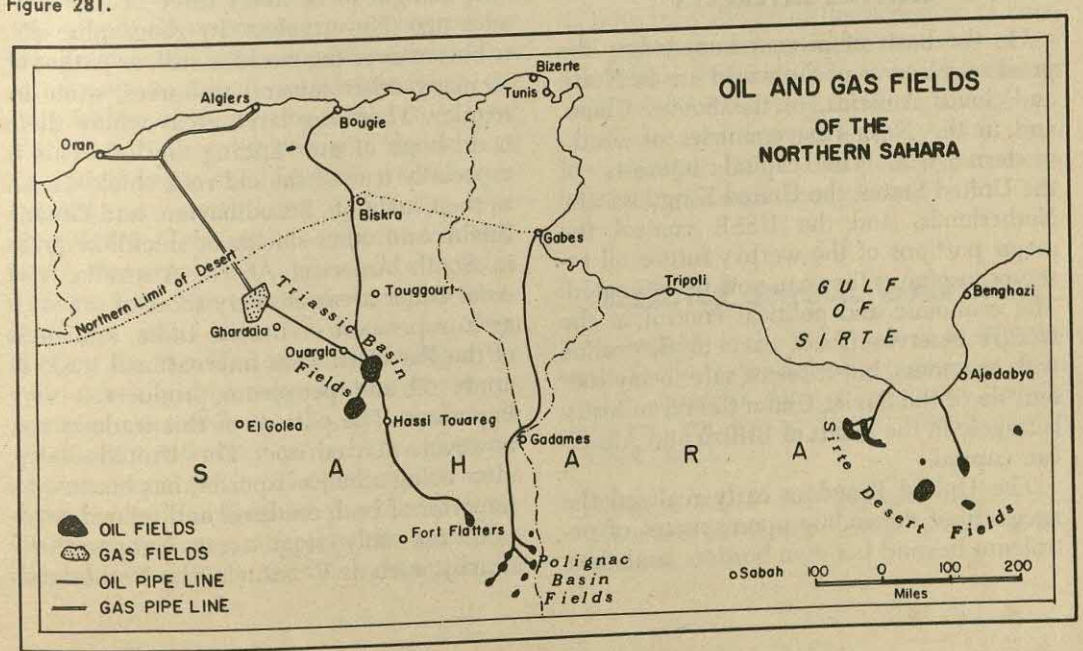
Northern Borneo consists of Sarawak, Brunei, and North Borneo. Production is mostly in Brunei. India, Pakistan, Burma, and Japan produce only comparatively small quantities of oil and gas. China is reported to have larger production, but only unofficial estimates are available, which range between 10 and 30 million barrels per year. Little is known about production and potentialities of China. The most favorable conditions appear to exist in the remote western parts of the country.

Africa. This continent has never been credited with any large oil potentialities. Much of the interior consists of old, crystalline, shieldlike areas, sometimes partly covered by comparatively thin sedimentaries of terrestial, and not marine, origin. In such regions the likelihood of finding oil in commercial quantities is slight. However, in some parts of the continent marine sediments of considerable thickness overlie the old rocks. This is the case in northern Africa from northern Egypt, through northern Libya, the northern Algerian Sahara, and from there northward to the Mediterranean and westward to the Moroccan coast. Similar, but smaller areas are found in western Africa, the lower Niger-Benue region of Nigeria, and other coastal areas of limited extent farther south and along the eastern shores of the continent. (See the continental map of Africa which precedes the text.)

Oil has long been produced in Egypt, but production has remained modest, between 20 and 30 million barrels. Most of the Egyptian crude is heavy.

Major discoveries have been made recently in Libya in the Syrte desert, south of the Gulf of Sidra or Syrte. The fields lo-

Figure 281.



cated thus far are less than 200 miles from the coast, and pipelines to the coast have been constructed. Other major discoveries have been in the northern Sahara, near the Ouargla oasis, and still farther south in the Polignac basin, east and southeast of Fort Flatters. A large gas field has been discovered south of the Laghouat oasis. All of these are at some distance from the coast, the fields of the Polignac basin being as far as 750 miles from the Mediterranean coast at Algiers. Thus, long pipelines have had to be constructed (Fig. 281).

As a result of these developments the northern part of the Sahara, roughly north of the 25th parallel, has become the scene of much exploratory activity. Both Algerian and Libyan production have increased rapidly and are likely to increase further. Also Nigerian production has become significant. Elsewhere in Africa production is comparatively small as in the Republic of Gabon, Angola, Morocco, and a few other countries.

Australia. Australia has areas of crystalline rocks too extensive to warrant hope of any large percentage of potential oil land. Local pools or small fields may be found, but exploratory work to date does not indicate that, as a continent, it is likely to attain high rank.

CAPITAL INTERESTS

On the basis of present knowledge, the great oil reserves of the world are in North and South America, in the Soviet Union, and in the Near East countries of southwestern Asia. The capital interests of the United States, the United Kingdom, the Netherlands, and the USSR control the major portions of the world's future oil reserves insofar as they can now be estimated. The economic and political control of the world's reserves is not easy to determine with exactness, but it seems safe to say that outside of the Soviet Union the oil industry is largely in the hands of British and American capital.

The United Kingdom early realized the necessity of depending upon sources of petroleum beyond her own borders, and thus, almost at the outset of the modern petroleum age, she became powerful in the international operations field. Also in the United States, capital interests have become aware of the dangers of too great dependence upon domestic reserves and, therefore, have undertaken extensive exploratory and developmental programs in foreign countries, particularly in South America and in the Near East.

When coal was the bunker fuel of the day, the British developed coaling stations all over the world in order to give fuel service to ships in merchant commerce. With the shift to oil, she was in position to equip these stations for bunkering with petroleum and its products, and she took full advantage of the situation. However, with the ascendancy of oil and the greater flexibility that its use involves, the Americans, being major producers, became active rivals with Britain in providing the fuel and power needed for maritime trade. The present outlook is that this condition will continue, and that no one country will be in a position of virtual monopoly.

THE OIL TRADE

Thanks to scientific methods of exploration, oil in commercial quantities has been found to occur in many more areas than was thought to be likely three or four decades ago. Nevertheless, its geographic distribution over the world is still, as is that of so many other mineral resources, quite irregular. There are large areas where there is no hope of ever finding any oil. This is especially true of the old rock shields, such as the Canadian, Scandinavian, and Guiana shields and other shields or shieldlike areas in South America, Africa, Australia, and Asia. Other areas are very short of oil, such as Europe west of Russia, India, and most of the Far East. Thus international trade in crude oil and petroleum products is very important. The pattern of this trade is not, however, a fixed one. The United States, after being a major exporter, has become an importer of both crude oil and refined products, not only from areas comparatively nearby, such as Venezuela, the Netherlands

Antilies, Canada, Trinidad, and Colombia, but also from the Near East and even from an area as far away as Indonesia. The Soviet Union, not in the export market for many years, has recently re-entered it. Europe obtains much of its oil from the Near East, but North Africa has also appeared as an important source of oil. The details of the picture are complicated and changeable. A number of the "have not" or "have little" countries, such as the Netherlands, the United Kingdom, and others, for example, export considerable quantities of refined products by importing large quantities of crude. On the whole, however, the number of large, basic exporters is small, and that of the importers is large.

SUMMARY OF THE PETROLEUM OUTLOOK

The expanding use of liquid and gaseous petroleum products has already brought, and is continuing to bring, great changes in transportation, industrial processes, and industrial development. In addition, through new technological processes, it is possible to convert practically all the crude petroleum into valuable products and by-products. Petroleum thus has become an important raw material for the chemical industries.

Liquid and gaseous fuels have many advantages over solid fuels, such as coal, peat, and wood. Experiments are in progress for the purpose of improving the methods of liquefying coal and for determining the practicality of converting coal into gas at the mine. If these experiments should lead to normal commercial feasibility (under abnormal war conditions liquefaction was practised in Germany at comparatively high cost), most coal would be used as liquid or gaseous fuel. The effects of this upon transportation and industry would be even greater. In the United States at least the railroads would be deprived entirely of the revenue provided by the principal bulk commodity still being carried, though in decreasing quantities. The effects of such change would extend to practically every realm of industry, affecting the manufacture of rolling stock, the steel output, and a host of industries contingent upon coal and steel as key commodities.

The petroleum industry of the world thus far has been built largely upon the basis of American production. This can readily be understood if we bear in mind that until recently the United States had provided nearly two thirds of all the petroleum used in the world since 1860. Fortunately, even with that tremendous drain upon the original store of resources, the annual estimates of proved reserves have shown no decline in recent years. Proved reserves are the quantities of oil which, with reasonable certainty, it will be possible to produce in the immediate future. There are no estimates of the *total* amount of oil that may still exist in the bedrock of the United States.

Demand in the United States has continued to grow, exports have declined, and imports have increased. In recent years imports have greatly exceeded exports.

Within the United States the great need is that of continued and improved conservation. The efficiency of modern methods of oil exploitation is high. In the past, production methods were in too many cases negligent in conserving gas pressure in order that maximum production might be realized. Wells were drilled too close together. Spacing was not carefully planned, and unit operation of oil pools was in many cases avoided. However, the petroleum industry is now fully aware of the necessity of careful planning and scientific methods of exploitation. The only way in which efficient methods of conserving this irreplaceable resource can be carried on is to base them upon cooperation, rather than upon uncontrolled individual competition.

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23

The Nuclear Energy Minerals

geographic implications of their use

THE VITAL significance of energy to all forms of life has won world-wide scientific recognition. Life itself is a manifestation of energy, and to sustain it in any form demands replenishment from some source. The sun is the principal source of energy for the earth, and the sunlight of ages past has made possible the fossil fuels, coal, petroleum, and natural gas. These fossil fuels are being mined on a large scale and are not replenishable in terms of human history since their formation has required millions of years. The depletion of these major resources has long been a matter of concern to all scientists with an interest in the future of mankind.

Fortunately, during the past quarter of a century a major new source of energy has been discovered as a result of new processes applied to materials which had been known for some time, but whose potentials as yielders of energy had not been realized. The source of the energy lies in the atoms of various substances, or rather in the nuclear part of the atoms, and hence this type of energy is called *atomic* or *nuclear* energy. The principal substances that, in the present state of our knowledge, can be made to yield this type of energy are closely related metals, namely uranium, radium, thorium, and lithium, plus one produced artificially, plutonium. Of these, uranium holds first place and is most widely known.

Energy is used in the production of power. When the first bomb was exploded at Alamogordo, New Mexico, July 16, 1945, a new term came into use—atomic power. *Atoms* were so named by the ancient Greeks, who believed them to be the smallest particles of matter and therefore indivisible. In 1919, however, Lord Rutherford found atoms were divisible, some of them releasing energy when divided.

URANIUM

Uranium, the heaviest of the known, naturally occurring elements, was discovered as early as the 18th century. It was first used as a pigment in ceramics, because in powdered form it had a bright yellow color. Two epoch-making discoveries were

made near the close of the nineteenth century, namely of radioactivity by Becqerel in 1896 and of radium by Curie in 1898. These prepared the way for the generation of a new form of energy, nuclear energy, the importance of which for the future life and activities of the world cannot be overstated. Uranium has become prominent in recent years because it is a major source of huge quantities of this type of energy. Considered only as a metal, it has few virtues because other metals are stronger, more durable, and make better alloys. Uranium combines readily in nature with a considerable number of other elements, thus giving rise to a correspondingly great number of uranium-bearing minerals, more than a hundred in all being known. These minerals contain varying amounts of uranium oxide, U_3O_8. The outstanding property of uranium is that it contains 0.7 per cent of an isotope, U_{235}, that is fissionable by slow neutrons with concomitant release of an enormous amount of energy.[1] Furthermore, its principal isotope, U_{238}, can be transmuted to another element, *plutonium*, which also is fissionable.

The uranium ores. There are two broad classes of uranium-bearing minerals and ores, namely the primary and the secondary. *Primary minerals* and *primary ores* occur associated with deep-seated magmas. Because of its early discovery and exploitation, *pitchblende* is the best-known example of this type. It is black to grayish-black in color, consists essentially of uranium oxide, and may contain up to 85 per cent of the oxide. In contact with the atmosphere, water, or other chemically active substances, the primary minerals undergo slow changes, and new substances are formed that differ chemically and physically from the original ones. These are the *secondary ores*, of which carnotite is the best-known example. Carnotite varies in color from lemon yellow to orange and contains about 50 per cent U_3O_8.

While uranium-bearing minerals are widely disseminated in many rocks, a certain degree of concentration is essential to successful exploitation. Discovery of such concentrations is possible by the use of instruments and by drilling and sampling.

Nuclear energy. In order to acquire a basic concept of nuclear energy it is necessary to recall the fundamental Einstein thesis that matter and energy are essentially different expressions of the same thing.[2] As mentioned above, the old theory of the *indivisibility* of the atom was abandoned, and its *divisibility* was recognized.

In the case of the atom bomb, an illustration of the "splitting of the atom," or rather fission of the U_{235} nucleus, it is claimed that there is a decrease of only 0.1 per cent in the rest mass, and yet a terrifying force is liberated, a force that staggered the comprehension of the most learned specialists in the field of explosives.[3]

The other process of liberating nuclear energy is exemplified by the so-called hydrogen bomb, wherein the fusion of 4 hydrogen nuclei to form helium entails a transformation of 0.7 per cent of the mass into energy. Yet even this small fraction of the energy of hydrogen nuclei means a frightening liberation of power.

Thus far U_{235} is the most efficient and the most practical fissionable element, and therefore uranium, from which it is derived, constitutes the key substance for the development of nuclear energy for various purposes. Most popular interest has been aroused by the explosions of bombs and the firing of weapons, but scientific attention has, for some time, been directed to the problem of controlling the liberation of energy both as to rate of discharge and the quantities of energy released. The potential destructiveness of suddenly released nuclear

[1] While *fission* implies splitting of the atom, *fusion* implies combining atoms of the same type.

[2] Einstein in 1905 submitted the formula that represents this relationship, $E = MC^2$, in which E refers to energy measured in ergs (work done in giving a two-gram mass a speed of one centimeter per second). This is equal to M, the mass measured in grams, times the velocity of light squared, C^2. It should be recalled that the velocity of light is about 186,000 miles per second.

[3] "Rest-mass" refers to matter at rest, not in motion relative to its surrounding matter. Matter set in motion undergoes a measurable change in mass.

energy has been recognized ever since the first bomb was exploded at Alamogordo in 1945. The terrible effectiveness of such explosions was demonstrated in warfare shortly thereafter, and since then the development of nuclear power for military purposes has proceeded at such a pace that its potential hangs like a threatening cloud over practically every country in the world.

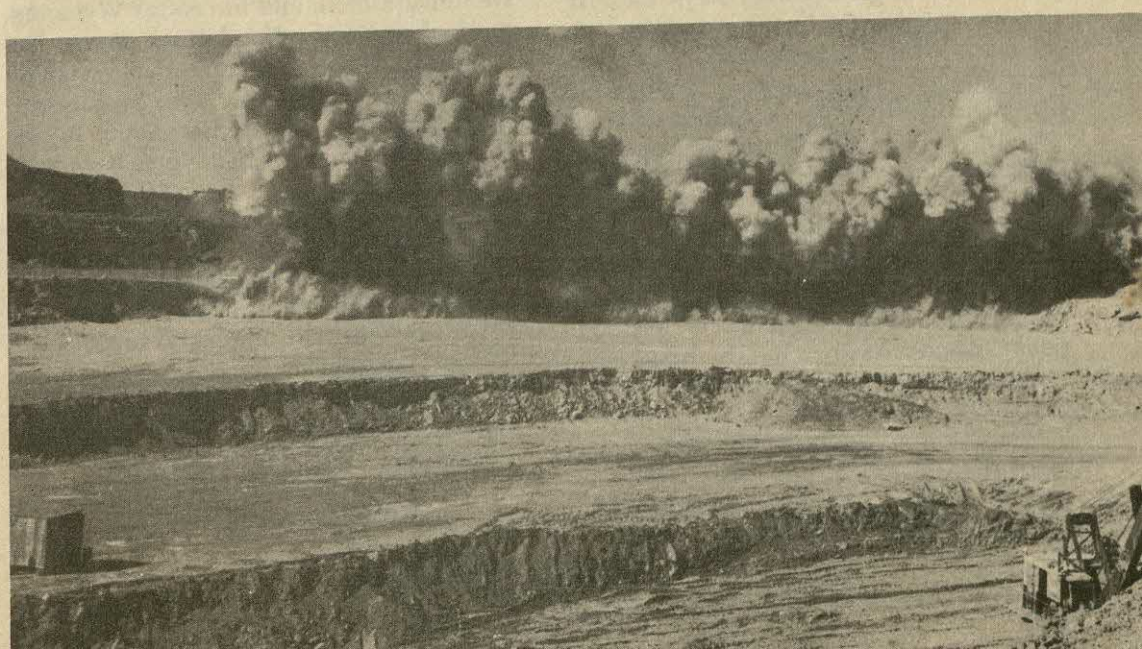
Control of nuclear energy is not and should not be an issue viewed only from a military point of view. Atomic energy is already a source of power for peaceful purposes, such as the generation of electricity, food preservation, and others, and undoubtedly many new ones will be found in the course of time. Thus uranium and nuclear energy may help to improve the daily life of human beings through the years ahead. And so the questions arise—where are the known, workable uranium deposits; how extensive are they; and what are the hurdles to be taken before their utilization becomes practical?

World distribution of uranium. Prior to World War II, little organized effort had been made to locate workable ore deposits, and the principal ones then known were those from which radium had been produced, especially those in the Great Bear Lake area of Canada; Katanga, Africa; and the Saxonian Ore Mountains or Erzgebirge in Europe. The discharge of the bombs at Hiroshima and Nagasaki in August, 1945, gave notice to the world of the enormous amounts of energy contained in atoms, energy which was used for destructive purposes, but which could, if harnessed, also be used for constructive purposes. Thus the Atomic Age began, definitely not under the best of auspices.

In most countries the search for uranium ores then began with almost frantic haste. In the United States the search appealed to so many people that one was reminded of the gold-rush days in California and the Klondike. The results of this search during the past decades have made possible actual production of uranium in all continents except Antarctica. Principal known areas of production during recent years have been northwest Canada, from the Great Bear Lake region southward and eastward to the Lake Ontario area; the Colorado Plateau of the United States and other areas in the western states; the Saxonian Ore Mountains of Czechoslovakia and East Germany; South Africa; and Australia.

Fig. 282. Explosives are used to break the solid benches or terraces of open pit mines into pieces small enough to be handled by power shovels to be loaded into trucks for disposal as waste rock or uranium ore.

Courtesy Anaconda Co.



THE UNITED STATES. Concentrations of uranium have been reported from many sections of the United States. The area from the Rockies to the Sierras is perhaps the world's largest known uranium province. During recent years commercial production has been reported from 13 states, but 4 states—New Mexico, Wyoming, Colorado, and Utah—produce 85 to 90 per cent of the nation's total output. Sizeable quantities have also been produced in Arizona, Washington, South Dakota, and other scattered locations.

The Colorado Plateaus hold front-rank position in development and in known reserves. The producing area extends from the Uinta Mountains of Utah to the Zuñi Mountains of New Mexico and from southwest Utah to the San Juan Mountains of Colorado. During the early stages of World War II, extensive field studies were carried on in this area in search of vanadium, and thus many details of stratigraphy and geologic structure were learned which later were of great help in the search for uranium-bearing layers. Large-scale uranium mining may be said to date back to 1948, when the Atomic Energy Commission set up a vast system of exploration, ore buying, and stockpiling. The layered structure, the deeply cut canyons, and the arid climate, which allows but little vegetation, all made rock outcrops readily visible although not so readily accessible (Fig. 282). Exploration during the earlier days was carried on extensively by jeep and by foot traverse. While in some remote sections these methods are still in use, roadbuilding has made many areas accessible to larger wheeled vehicles, and the use of planes and helicopters has aided greatly in reconnaissance work. The excellent visibility in the area enables geologists and prospectors to view the larger features from the air and thus to choose favorable sections for more detailed ground investigations. Grand Junction, Colorado, has become the best-known operational center of the uranium industry of the Colorado Plateaus.

New Mexico leads in the mining and processing of uranium ore. The largest industrial center is Grants, about 75 miles west of Albuquerque, and much of the mining is carried on in an area extending some miles east and west of Grants. The ore occurs in sedimentary rocks, and some of it is quite far below the surface (Fig. 283). Where open-pit mining can be practised, huge quantities of waste rock material are removed in order to obtain the ore, and even the ore thus obtained is reported to have an average tenor of only one tenth of one per cent uranium oxide, U_3O_8.

The transformation of the ore into a semi-finished product, popularly known as "yellow cake," consists of a series of processes, ranging from massive haulage to operations which require great precision. The various stages of treating the ore are typically illustrated at one of the large plants near Blue Water, a few miles west of Grants. The ore is delivered by truck and rail; there it is dried, crushed, and ground to a consistency almost as fine as flour. Chemicals are then added which cause the uranium to go into solution. Subsequently other chemicals are added which cause the uranium oxide to be precipitated. The waste material is discarded, and the precipitate (yellow cake) is cleaned, filtered, dried, and shipped to the Atomic Energy Commission in 55 gallon drums (Fig. 284).

In 1951 uranium deposits similar to those found in the Colorado Plateaus were discovered in the western part of the Black Hills, and subsequently other discoveries were made there and in central Wyoming, particularly in the Wind River Basin. Development has been so rapid that Wyoming has become one of the four major uranium-producing states. Here and in the Colorado Plateaus the richer ores have been found in ancient river channels, in association with fossil vegetation such as carbonized wood and lignite. They are concentrated in ore bodies of moderate size, some of small extent, others of larger. Ore content also varies. The uranium content of ore bodies in sedimentaries is generally lower than that of the bodies which contain minerals of the primary type and which are associated with igneous rocks.

The major part of the production so far has come from sedimentary rocks, and

lesser amounts have come from deposits closely associated with volcanic activity. The Marysville deposits in Utah and the Front Range deposits of Colorado belong in the latter category.

The Marysville, Utah, deposits are located in an area of former volcanic activity and the associated occurrence of hot vapors and solutions. Surface outcrops contain brightly colored secondary minerals, but at greater depths pitchblende has been discovered. The area of production is small, but the ore bodies are relatively deep-seated.

Because of the widespread occurrence of visible particles of uranium oxide, it was early believed by some that productive ores might readily be found in various igneous rocks. Extravagant statements were made as to potentials in areas of such rocks, as in the crystalline Appalachians, but thus far no discoveries of ore bodies of commercial size and grade have been reported.

CANADA. The uranium deposits are in the area of pre-Cambrian rocks known as the Canadian Shield. The original important uranium discovery is credited to Gilbert LaBine, who as early as 1930 located a vein along the south shore of Great Bear Lake, a short distance south of the Arctic Circle. These deposits were from the outset valuable as a source of radium, but later became prized as a source of uranium ore. Intensive mining for uranium began during World War II, when it was needed for the Manhattan Project. The original mine and the production were taken over by the Canadian government, a move deemed necessary under the prevailing war conditions.

Uranium deposits in Canada are numerous and varied, extending along the frontal areas of the Canadian Shield from the Great Bear Lake region in the north to the north shore of Lake Athabasca, about 500 miles farther south, and from there to the Blind river area located about 90 miles east of Sault Ste. Marie. Vein-type deposits prevail in the northern areas. In the Blind river area the ore occurs disseminated in conglomerate beds. It is of low grade, but of such wide and extensive occurrence that with the development of more efficient methods of concentration it has proven to be a very important source of uranium.



Fig. 283. The well-known Jackpile mine on the Laguna Indian Reservation, 35 miles east of Grants, New Mexico. It represents the removal of nearly one million tons of earth and rock in the quest for uranium.

Courtesy Anaconda Co.

THE SOVIET UNION. All data regarding uranium in the USSR are closely guarded secrets, particularly as to mining centers, quantities and quality of output, and processes of ore treatment. Various writers have presented estimates and expressed opinions, but it appears advisable to classify them as not more than intelligent guesses. However, since it is known that large numbers of scientists have been engaged for a number of years in exploratory work for uranium ores, it seems certain that great progress has been made during recent decades. Reasonable estimates rate the Soviet Union high in potential supplies of uranium. The great Russian achievements in the field of nuclear power since 1950 surely justify the belief that the country is well supplied with resources of nuclear minerals, and that Soviet scientists are succeeding in making good use of them.

The areal distribution of uranium ore in the Soviet Union is not definitely known. Mining for uranium in the Saxonian Ore Mountains, on the boundary between East Germany and Czechoslovakia, is under Soviet control. It was from ores mined in these mountains that the Curies isolated radium, a product of uranium, and for many years the mines concerned remained the world's major source of radium. The total amount of uranium oxide that has been mined here since the end of World War II is not known.

It is a widespread belief, based on information prior to 1944, that the principal uranium deposits in the USSR are in the sandstones and limestones of the Fergana basin, near Tashkent. There undoubtedly are other deposits.

EUROPE. Although the complex structure of western Europe is a factor favorable to the concentration of ore bodies, few important discoveries of uranium ore have thus far been reported. The districts of some importance are mostly in central and western Europe. In addition to the Saxonian Ore Mountains discussed previously, Cornwall, England, the highland area of Portugal, the Central Plateau of France, and the black-shales area of Sweden should also be included.

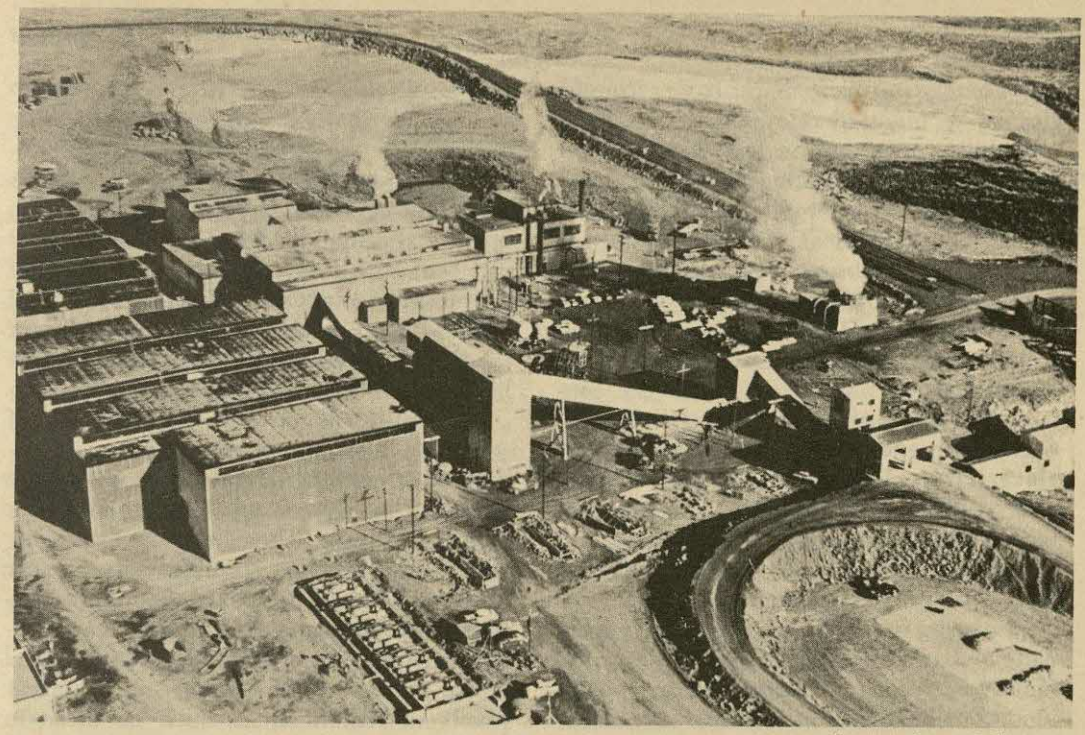
Portugal was an early producer of radium, but of late has been producing uranium. Secondary minerals are found at shallow depth near the surface, and pitchblende occurs at greater depth.

French production of uranium ores has been developed in the Massif Central and in the Vendée, at the southern edge of the Armorican Massif. It appears that France has made great strides scientifically in the development of her uranium resources, and it is common knowledge that she has developed bombs and nuclear warheads, tested in the desert areas of northern Africa.

AFRICA. When the United States Atomic Energy Commission first began to function in 1947, the bulk of the uranium was coming from Katanga, Africa, with smaller amounts from Canada and some from the western states of the United States. The best-known African supplier of ore was the Shinkolobwe mine in the heart of Africa, about midway between the east and west coasts of the continent and about 11° south of the equator. The first procurement arrangement of the Atomic Energy Commission was made during World War II with the Union Minière du Haut Katanga for uranium from the Shinkolobwe mine. From 1922 until a few years ago this mine was the world's major producer of radium and uranium. Reports indicate that the main ore bodies of the Shinkolobwe mine have been virtually exhausted.

Major interest in Africa is now centered upon the southern part of the continent. South Africa has a uranium industry based on recovery from tailings left by the treatment of gold ore. The uranium content of the tailings is low, averaging less than a pound of U_3O_8 per ton. However, since most of the ores are mined for gold, the mining costs need not be charged to uranium. In contrast to the ores of the Colorado Plateaus, where one ton of ore yields several pounds of uranium, several tons of South African gold tailings must be leached to yield one pound.

Although South Africa has reported the largest uranium reserves of any producing country, production will depend upon the extent of gold-mining operations from which the by-product uranium can be recovered.



Courtesy Anaconda Company

Fig. 284. Aerial view of uranium ore processing plant at Bluewater, near Grants, New Mexico. Shows extensiveness of the complex operations necessary to eliminate the gangue material and concentrate the uranium compounds into usable form.

Methods of production. In a broad sense, the two principal methods of mining uranium ore are the same as for many other metallic mineral ores, namely, open-pit and underground mining. In the United States production is about equal from open-pit and underground mines, whereas in Canada and South Africa production is entirely from underground mines. In the Colorado Plateaus large surface excavations are in operation, but are being supplemented by underground mining as the thickness of overburden increases (Fig. 283).

Ore processing involves solution and precipitation, as previously described, after which the yellow cake is sent to the Atomic Energy Commission refineries, which prepare it for the production of fissionable materials for peaceful purposes or for use in weaponry.

Uses of uranium. In the United States the Atomic Energy Commission, appointed by the President, has the responsibility for directing the development of atomic energy. It has encouraged private enterprise, however, to undertake the mining and processing of uranium ore. Since World War II the control of processing and marketing of uranium has continued in many countries to be a government monopoly. In the "free world" the United States has virtually controlled the size of the output through a plan of contracting in effect until the end of 1970. Since the uranium resources have been developed in all of North America to the point of potential surplus production, the policies and practices beyond that year will depend upon circumstances.

Other countries, particularly the Soviet Union, Great Britain, France, Canada, Australia, and China, have also set up atomic energy organizations.

The most spectacular use of uranium is, of course, for the manufacture of atomic bombs. The bombings of Hiroshima and Nagasaki and the subsequent release of numerous bombs for testing purposes by the Americans, the Soviets, and, later, by

the French in the Sahara have aroused visions of indescribable destruction as a probability in case of nuclear war. As a result, all the larger nations have increased tremendously their military expenditures under the general cloak of defense. All these have tended to obscure understanding and appreciation of the potential uses of nuclear energy for peace. Unfortunately, the vision of potential destructiveness has so blinded the public that few people realize the constructive aspects which have been achieved.

Nuclear energy for the generation of electricity. The major potential of nuclear energy for civilian use is its convertibility into electric and/or heat power, but until a few years ago it was not believed that, for ordinary economic purposes, nuclear energy would soon be able to compete with coal, petroleum, gas, and falling water. However, recent developments are beginning to make it feasible to construct nuclear power plants on a normal economic basis.

Several years ago the cost of constructing nuclear power plants was more than double that of equivalent thermoelectric plants. While the cost of construction continues to be higher, this ratio does not hold any longer. Cost of construction per unit of generating capacity varies considerably with the size of nuclear plants, very large plants being considerably more economical than small plants. It is therefore difficult to give a specific cost ratio, but for the larger type plants it is at present probably on the order of 1.5 to 1.4, with some further variations depending on geographical location. This is a not insignificant decrease. In addition, it can be expected that greater experience in construction and progressive standardization will tend to further decrease the difference in cost of construction.

General operating costs of nuclear plants are comparatively close to the cost range of conventional plants. It is true that maintenance of safety, the problem of the disposal of dangerous waste, and the need for highly skilled technical personnel all translate into higher costs, but when added up they still amount to only a small portion of the cost per unit of electricity.

The initial fueling cost is high, as uranium and its derivatives are expensive (even though only small quantities are needed), and the cost of fabricating fuel elements is high. However, if a large nuclear plant can operate at a high load factor, from 80 to 90 per cent, the fuel cost during a cycle of operation becomes much lower than that of a coal-fueled plant. This lower fuel cost tends to counterbalance more and more the high construction and other initial costs.

General ideas on the development of nuclear power have swung from overly enthusiastic expectations for the immediate future to overly conservative estimates for a farther future. They are now becoming more realistic. Not so long ago nuclear power tended to be looked upon as something specially suitable for remote and underdeveloped areas lacking in conventional power resources. Of course, small nuclear plants in remote areas, such as those in Greenland and Antarctica, can still be useful, but at this stage of development of nuclear power they must be looked upon as highly special cases, quite far removed from normal considerations of economic feasibility.

A basic fact at present is that large nuclear plants are most nearly economical. For plants of such size a large and dependable market demand is essential. This can be found only in areas that are quite highly developed industrially and rather densely populated, and where the power can be fed into a major grid. Under such conditions nuclear energy can be applied to base loading, and other fuels can be used for above-base load to peak periods. Nuclear energy finds its best chance to enter into the power-generating scheme in those portions of well-developed areas where costs of conventional fuels tend to be above the normal for the area.

Thus, contrary to some previous expectations, nuclear energy for power purposes tends to become economical first for areas of comparatively dense population. This is, of course, somewhat difficult to reconcile with the fact that the necessity to protect against potential hazards of operation is

such that isolated plant locations might be preferable. However, if increased distances of transportation of electric power become feasible, perhaps by means of direct-current transmission, the location of nuclear plants would become less of a problem.

Until recently the development of nuclear power has been shared by industry and government, with government assuming the larger share, partly because of its control of the fuel, partly because of the considerable amounts of capital involved, and partly for a number of other reasons. However, this is beginning to change. At least in the United States private capital is becoming more interested in the building of nuclear plants without, or with only a minimum of, government assistance. In the early 1960's in only 7 of the 17 or so nuclear power plants under construction or operating in the United States was the reactor owned by the government, while several other plants were in the process of being built by private capital, or application had been made by private capital for the construction of plants.

In Great Britain the first nuclear energy was fed into the national grid in 1956, and it is anticipated that by the end of the 1960's about 10 per cent of the national power requirements can be fed into the grid by a dozen nuclear plants. To the extent feasible, these plants will normally be located at maximum distances from existing coal fields and in areas where there has been a marked increase in the demand for electricity. Other nations are also building or have built nuclear power stations.

Thus nuclear power has come—not in the spectacular way expected by some, supplanting within a short time all other forms of energy—but by taking its place, undoubtedly a place of growing importance, in an orderly manner in the established scheme of power generation.

Among the less well-known but constructive uses of uranium are its use in food preservation, medical therapy, and scientific research, the latter having led to numerous new products and methods of treatment. The utilization of uranium in chain-reacting atomic piles yields valuable by-products in the form of isotopes of many elements that, as a result of scientific research, can be used in medical therapy. These are actualities of the present and give promise of rapid advance in number and in usefulness in the near future.

World trade. The United States is probably the greatest buyer of uranium, with the Soviet Union not far behind. Canada exports largely to the United States and to England, and the uranium of South Africa is exported primarily to the United Kingdom and the United States. East Germany, Czechoslovakia, and Bulgaria provide ore to the Soviet Union.

Reserves. The element uranium is present almost everywhere in the earth's crust. There are many rock masses with a uranium content of one part in 100,000, but this concentration is much too low for any mining operations by present processes. Eighty or more minerals contain substantial amounts of uranium, but only a few of them have been found to occur in concentrations that can be considered as ore bodies. Under present mining and processing methods, an ore, available in quantity, should contain at least three to four pounds of uranium oxide per ton of rock. Presently known low-cost reserves of the "free world," located primarily in the United States, Canada, South Africa, France, and Australia, are estimated at about one million tons. Estimates now current are likely to be on the conservative side. Before reliable estimates of ultimate reserves become available, world-wide exploratory studies must be made in field and laboratory. The tasks of locating, mining, and processing ores for industrial purposes are a challenge to man's ingenuity.

RADIUM

Radium is a radioactive metal found in uranium ores. The content, in ores not subsequently enriched or impoverished by geologic processes, is in a constant ratio of approximately one fourth of a gram of radium per short ton of uranium oxide. In

refining, the radium is separated from uranium by precipitating it with radium-barium sulfate. The sulfate is converted to a soluble salt and purified by repeated fractional crystallizations.

The genetic relation between radium and uranium accounts for the presence of radium only in uranium minerals. The small fraction of radium and the complexity of chemical separations and fractional crystallizations help us to realize the basic causes of its high price in metal form.

The significant property of radium is its radioactivity, the emission for a very long period of time of penetrating rays that are similar to, but not true, light waves. Radium is used in therapeutic treatment of some superficial skin diseases and for some time was used similarly for some more deeply seated ailments. It is also used to make luminous paint and to take radiographs of castings and welds, and for a time it was used to log oil wells. More recently radioisotopes produced in chain-reacting atomic piles have largely displaced radium for a number of purposes.

In the United States peak production of only 32 grams was reached during World War II in 1945. In a representative prewar year, 1938, world production totalled 146 grams, of which Canada produced 75 grams; Belgium, 60; Austria, 5; Portugal, 3; the United States, 2; and Germany, 1. It is believed that the Soviet Union also produced some radium before World War II, but reliable data are not available. The radium refined in Canada and Portugal was from domestic ores, but that refined in the United States, Germany, and the Soviet Union was only in part from domestic ores. Belgium then refined radium from Congo (Katanga) ore, and the United States refined Canadian ores.

The half life of radium is 1,620 years. While this is long in terms of human experience, it is only a very brief period in terms of the geologic time scale, and any radium present at the time of formation of the earth has long since completely disappeared. It is only because a new supply of the element is continually being generated by the disintegration of uranium that radium is found at the present time.

The economic returns have shifted from excessively high to low, as costs have changed with new discoveries, and prices with variations in demand. For example, the price of radium per gram was $10,000 in 1904, but reached an all-time high of $135,000 per gram in 1918. Since World War II demand and prices have declined, so that in 1957 the quoted price was only $15,000 per gram.

World production was reported as approximately 50 grams in 1961 and rose markedly to about 1,900 grams in 1940. Production declined sharply after 1950 because for most of the uses of radium substitutes had become available at lower costs.

PLUTONIUM

Plutonium is an artificially produced metallic element. It was discovered in the form of Pu_{238} by Glenn Seaborg and A. C. Wahl at the University of California, Berkeley, in 1941. While there are several types, represented by numbers, Pu_{239} ranked first in importance because of its property of being fissionable with slow neutrons, thus making it useful as a nuclear fuel. Nuclear reactors are the most important source of plutonium.

The energy available from the only naturally occurring fissionable isotope, U_{235} is not large when compared with our fossil fuel reserves because only one out of 140 parts of natural U_{238} is U_{235}. However, U_{235} can be used to get a fission chain reaction started, and this in turn provides excess neutrons that can be absorbed in the much more abundant isotope, U_{238}, for the production of Pu_{239} and Pu_{241}, which also are fissionable. This process of transmuting U_{238} into fissionable plutonium in "breeder reactors" makes it possible to burn a large portion of the uranium. This in turn makes it possible to use low-grade and high-cost uranium sources not previously deemed suitable for power purposes.

The discovery of plutonium and its use in breeder reactors is estimated to extend

indefinitely our reserves of potential energy sources throughout the world. These potentials can be used for peaceful industries and thus spur higher standards of living everywhere.

THORIUM

Thorium is a grayish-white metal discovered by Berzelius in 1828, and it has long been noted chemically and industrially for its use in giving a brilliant glow to gas mantles, a use that was predominant for decades preceding World War II. Other nonenergy uses are for alloying with magnesium, for chemical and medicinal purposes, and for electric and radio-tube filaments. Thorium oxide (ThO_2) has a melting point of about 5,000°F., and therefore is in demand for special refractories.

The major importance of thorium now is due to its potentialities in the field of nuclear production. A number of synthetic isotopes have been prepared from thorium by transmutation reactions, the most important being the isotope U_{233}, produced by neutron reaction on ordinary thorium. This isotope is fissionable with the liberation of energy similar to that produced by U_{235}. Thus in the production of nuclear energy, thorium is referred to as "fertile material," and its transmutation into U_{233} as the *breeding cycle.*

Monazite has been the principal ore mineral of thorium. It occurs in unique vein-type deposits in South Africa, but elsewhere largely in river and beach placer deposits. The largest known deposits of this type are along the Travancore and Malabar coasts of India and the east coast of Brazil from Rio de Janeiro to Baía, where beach sands, so-called black sands, mined primarily for titanium, generally contain 1 to 10 per cent of monazite. Monazite in India contains from 8 to 10 per cent of ThO_2, and that in Brazil about 6 per cent. In the United States some monazite has been obtained from dune sands along the Florida coast near Jacksonville and from gold-bearing gravels in Idaho.

The announcement in 1945 of the potentiality of thorium as a source of nuclear energy brought virtually world-wide government control of the element and restricted its movement to channels specified by the several governments.

In general, it may be said that "black sands" occur in many parts of the world, and that the total monazite content is undoubtedly great. If continued progress in the generation of atomic power leads to the use of thorium as a potent "breeder fuel," it may become recognized as one of the highest-ranking mineral assets of our times.

LITHIUM

Lithium was discovered in 1817 by Arfvedson in Sweden, but for more than a century it remained virtually unknown. Only during the past half century has lithium come to be used industrially because of two unique properties: it is the lightest of all the known solid elements, and at ordinary temperatures it has a higher specific heat than any other substance except water. Its uses range from that in medicines, one of its earliest uses, to use as flux in welding and use in the manufacture of storage batteries, in glass-making, and in ceramics.

There are many kinds of lithium-bearing minerals, but *spodumene* is the best known. It occurs usually in tabular pegmatite bodies which must be of sufficient size to justify mass-mining operations.

So far as it is known, the United States has accounted for more than 50 per cent of the world's production and consumption of lithium ores. Among the other prominent lithium-producing countries of the world are Canada, Argentina, Brazil, Australia, and a number of countries in Africa, as well as the Soviet Union and countries in Asia. In virtually all countries lithium compounds have been found, but usually in small or scattered quantities.

The possibility of the use of lithium for energy purposes in a fusion reactor was formerly considered too remote for practical consideration. However, recent advances in research have been made which may change that idea. The possibility that lithium may

provide raw material for the release of atomic energy by the fusion process is looked upon with favor by some scientists of high standing.

SUMMARY

The recognition of the importance of the nuclei of atoms in relation to energy generation can be deemed the most significant element of material progress during the past decades. Atomic energy and resultant power have inaugurated the Atomic Age, a term which implies the liberation of energy in a *controlled* manner, either through the fission of atoms or through fusion, and for constructive, rather than destructive purposes. Among the fissionable minerals, the most effective seem to be uranium and thorium, whereas lithium and similar metals are of greater promise for the fusion process. There are, however, a number of other raw materials in the mineral world which are known to have such energy potentials.

The Atomic Age was introduced under war conditions. Under the canopy of national defense, almost innumerable structures have been erected in nearly all countries of the world at the cost of billions of dollars. These have been built as a result of war measures and also when the objective was self-defense. That they have affected the economic geography of the world is generally recognized.

However, the constructive aspects of the Atomic Age should be emphasized. Nuclear processes will give access to large amounts of energy for peaceful purposes. Also, as a result of atomic research many new products have been developed with applications or uses in the areas of health and sanitation, in the creation of new precision instruments, and perhaps most of all in the progress of understanding more of life itself by the studying of cellular structure. May these constructive aspects of fission and fusion become dominant so as to help mankind to a better material life, rather than to destruction!

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24

The Iron and Steel Industry

index of industrialization

FOR EVERY ton of copper produced in the United States a hundred tons of steel pour from the furnaces. Steel is used in all machines and machine tools, in nearly all durable goods, such as automobiles, refrigerators, etc., it forms the internal structure of large buildings and is essential throughout the manufacturing industries. Steel is so widely used because of its basic high strength, comparatively low bulk, and low cost. It is a versatile product which can be tailored to diverse and specific needs: some steels have high tensile strength (cables); others have high resistance to corrosion (stainless steels), great resilience (springs), or resistance to impact loads (earth-moving equipment) and to wear. Steels which have one or another of these properties, or some combination of them, can be produced in quantity, making it an inexpensive metal costing about $.08 per pound. Copper and aluminum, other common metals, cost three to four times as much. The low cost is related to several factors. The iron minerals from which steel is made are of quite frequent occurrence in the outer crust of the earth; iron can easily, and at low cost, be reduced from the deposits rich in iron minerals, and steel can then be made from the iron.

In our time steel is almost synonymous with industrialization, and per capita steel production of countries is almost a direct index of the degree of their industrial development. For example, highly industrialized countries such as the United States, the Soviet Union, West Germany, and Britain have an annual production of from 700 to 1,000 pounds of steel per inhabitant, while countries less developed industrially, such as China, India, and Brazil have steel production of under 50 pounds per inhabitant, and some of the new countries of Africa may not have any iron production.

THE IRON MINERALS

There are a considerable number of minerals that contain iron, but four are outstanding because they are the most common ones that occur in exploitable iron-ore deposits throughout the world: hematite, magnetite, limonite, and siderite. Taconite is

not a mineral, but a siliceous rock which has an iron content of about 30 per cent (both hematite and magnetite) and which in the United States occurs in quantity in southern Minnesota and adjacent Michigan, where it is called jaspilite.

Hematite. Hematite (Fe_2O_3) is the most important industrial iron mineral in the United States. The mineral itself contains nearly 70 per cent iron; but the ore as mined always contains other matter in addition to the mineral, referred to as gangue, so that the actual percentage of available iron may be considerably less. For example, the hematite mined in Minnesota and Wyoming in recent years has averaged from 48 to 52 per cent iron. If the content of other matter becomes higher, and therefore the iron content lower, the economic value of the ore is considerably reduced, and the ore may even become practically unexploitable. Hematite is mostly reddish or so-called ocher red, although some is almost black or even bluish. While not the most widespread of the iron oxides, in North America hematite has ranked first in industrial importance because of the relatively high grade of the deposits in which it occurs and the ease with which the ore can be mined and smelted.

Magnetite. Magnetite (Fe_3O_4) is the richest of the common iron minerals. Some varieties act as natural magnets and are referred to as *lodestone*. The color is darker than that of hematite or limonite, varying from deep dark brown to blackish. As a mineral, magnetite contains 72.4 per cent iron, but in actual mining operations the ore is considered to be high grade if it yields more than 60 per cent iron. Magnetite mined in Nevada is reported to have yielded 65 per cent iron. Lean ores contain less than 35 per cent iron.

Limonite. Limonite or "brown ore" is the most common of the iron oxides. It is a chemical compound in which water in varying amounts is an essential constituent. Much of it is goethite, of which the formula is $HFeO_2$, which corresponds with a water content of 10 per cent. However, many limonites hold additional water in unbound form. It is widely distributed over the earth and occurs in varying degrees of hardness; its color ranges from yellow to dark brown. Limonite commonly gives a yellowish or brownish color to the subsoil, but becomes an ore only where it occurs in bodies large enough and with sufficient iron content for successful mining operations. Recoverable iron content of limonite ores is usually well below 50 per cent. Limonite mined in Alabama has of late been reported as yielding, on the average, about 38 per cent iron. The same kind of ore mined in France and in England is deemed satisfactory if it yields above 30 per cent iron.

Siderite. The three minerals briefly described constitute the principal sources of primary iron in the world today. All three are essentially chemical compounds, in varying ratios, of the elements iron and oxygen. Earlier, much dependence was also placed upon a carbonate of iron known as siderite, consisting chemically of iron, carbon, and oxygen ($FeCO_3$). Siderite contains about 48 per cent metallic iron, but the ore as mined contains much other matter, as a result of which iron content is materially reduced. Although the percentage of metal is not as high as in the oxide ores, siderite is usually free of the kinds of impurities that are difficult to eliminate in the smelting process. Siderite was in large measure responsible for the quality of steel products which long ago gave Solingen, in Germany, a high reputation in the manufacture of sharp-edged instruments.

Iron-ore deposits which contain one or more of the iron minerals discussed above are quite numerous. This is especially true of the so-called bog-ore deposits, which contain mostly limonite, and which are found in numerous bogs scattered through all areas of recent continental glaciation. In New England, for example, bog ores long were the basis of the colonial iron industry. Modern methods of iron smelting and steelmaking, however, require large amounts of ore, and as a result most small deposits now are of little or no economic importance. Vast iron-ore deposits of high iron content are not numerous, and among the thousands of

deposits that have been identified geologically only comparatively few are of industrial interest.

DISTRIBUTION OF IRON ORES IN ANGLO-AMERICA

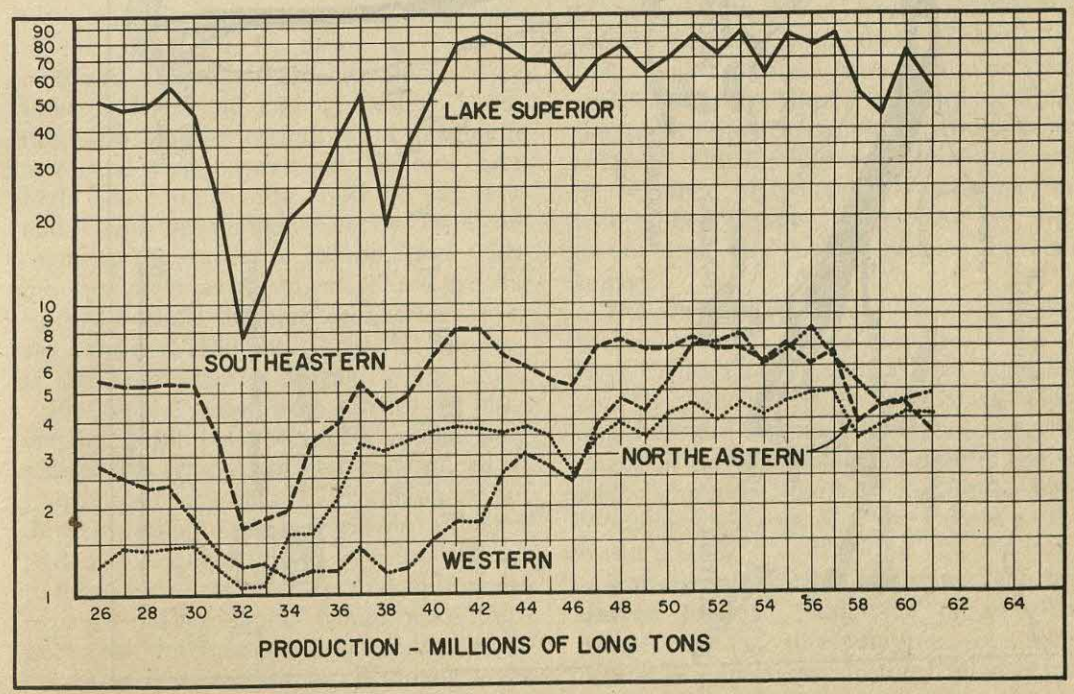
In the United States iron ore is produced in four main districts: about three fourths of the ore comes from the Lake Superior district, while the remainder is fairly equally divided among the northeastern, southeastern, and the western districts.

The northeastern district. The two principal areas of iron-ore production in the Northeast are the Adirondacks region of New York and the Cornwall area of Pennsylvania. The latter extends across New Jersey into southeastern New York and is often referred to as the southeastern New York-New Jersey field. The total output of ore in the northeastern states has been about 8 to 10 million long tons annually during recent years. Magnetite, the principal ore, has a relatively high market value per ton because of its quality and accessibility to markets. The ores of New York and eastern Pennsylvania are important local sources for the nearby smelting industries, although total production is relatively small compared with that of some of the other districts (Fig. 285).

The southeastern district. The only important mining area in the Southeast is near Birmingham, Alabama, though some iron is mined in Georgia and Tennessee. The average annual output of the district is about 6 to 8 million long tons. Hematite and limonite are the principal ores. The southeastern district has the advantage of nearness to the coking coal found in the Appalachian Plateau immediately westward.

The Lake Superior district. The producing area of the Lake Superior district is confined to northeastern Minnesota, the Upper Peninsula of Michigan, and a small section of northern Wisconsin. This area still furnishes approximately three fourths of the total iron-ore output of the United States. The output comes from the so-called iron

Fig. 285. Annual production of iron ore in each of the four generally recognized districts of the United States. Note that, even in recent years, production of the Lake Superior district has been almost as much as that of the other three districts combined.



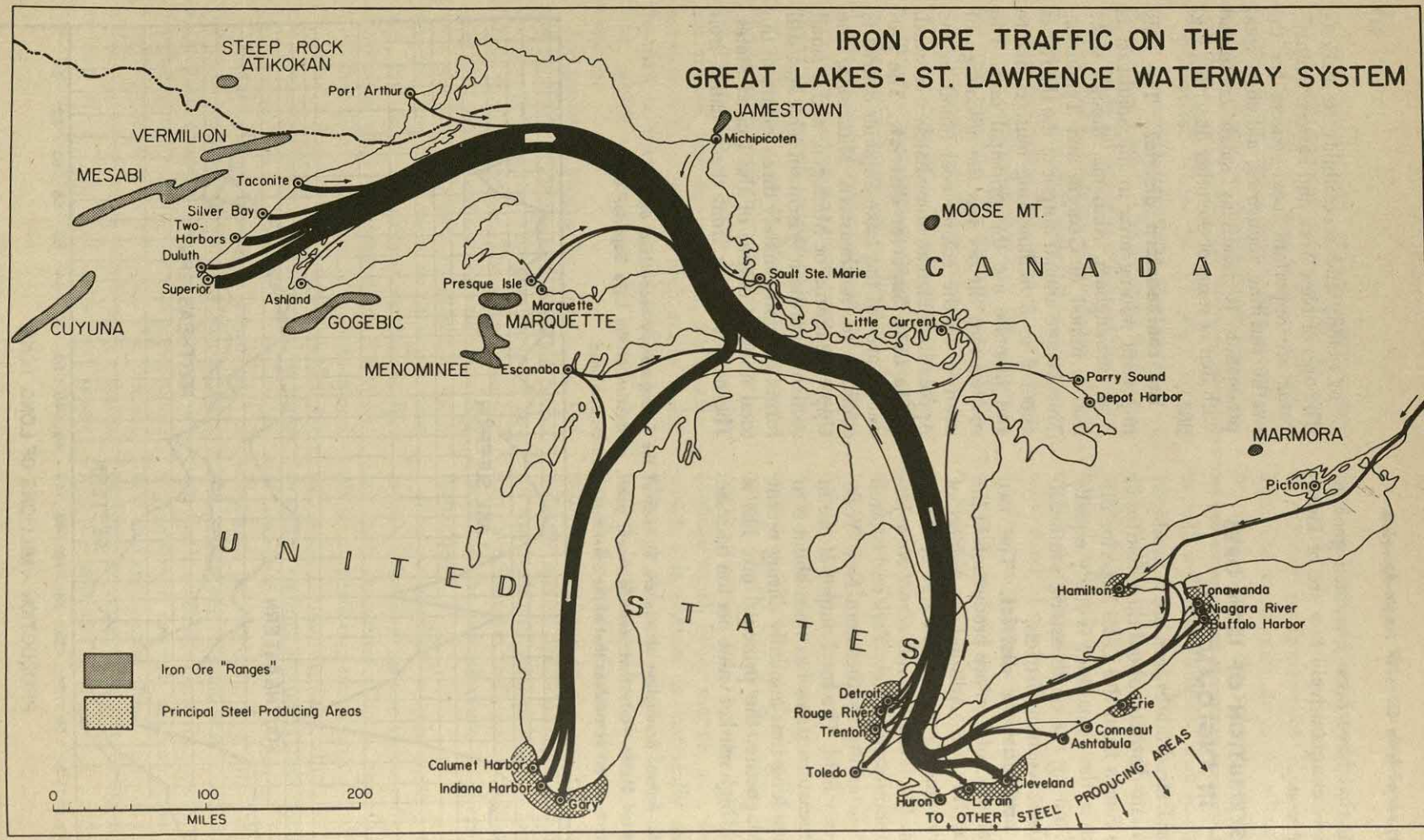

IRON ORE TRAFFIC ON THE
GREAT LAKES - ST. LAWRENCE WATERWAY SYSTEM
STEEP ROCK
ATIKOKAN
Port Arthur
JAMESTOWN
Michipicoten
VERMILION
MESABI
Taconite
Silver Bay
Two-
Harbors
Duluth
Superior
Ashland
MOOSE MT.
CANADA
Sault Ste. Marie
Presque Isle
Marquette
MARQUETTE
GOGEBIC
CUYUNA
Little Current
MENOMINEE
Escanaba
Parry Sound
Depot Harbor
MARMORA
Picton
UNITED STATES
Hamilton
Tonawanda
Niagara River
Buffalo Harbor
Iron Ore "Ranges"
Principal Steel Producing Areas
Detroit
Rouge River
Trenton
Erie
Conneaut
Ashtabula
Calumet Harbor
Indiana Harbor
Gary
Toledo
Cleveland
Huron
Lorain
TO OTHER STEEL PRODUCING AREAS
0
100
200
MILES

Figure 286.

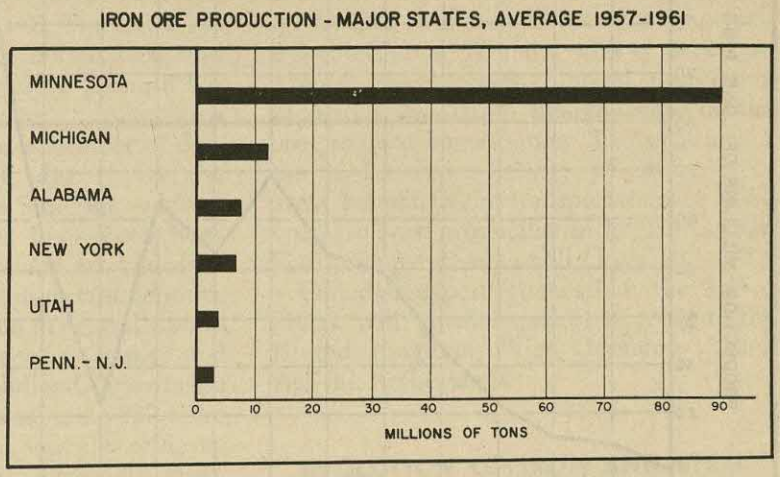


Figure 287.

ranges, the Mesabi, Vermilion, and Cuyuna ranges of Minnesota and the Gogebic, Marquette, and Menominee ranges of Michigan and Wisconsin. The Mesabi is the most important, and normally produces about three times as much as the other ranges put together (Figs. 285, 286, 287).

For many decades the principal ore has been hematite, occurring in large bodies generally soft enough to be mined with little use of explosives. Most of these bodies also were located sufficiently close to the surface to be exploitable by means of open-pit methods, although there has always been some underground mining. Besides hematite, also smaller quantities of magnetite were, and still are, produced. The ores had a high iron content, often over 55 per cent, and could be shipped directly from the mines to the centers of consumption, without any previous treatment. These are the so-called direct-shipping ores, which ever since the mid-1850's have been the mainstay of the Lake Superior district.

During the period from 1855 to the present time a total of about 3,500 million long tons of this type of ore have been mined. It is estimated that another 700 million tons of direct-shipping ores are available, although part of this quantity will be more difficult to mine and therefore may tend to be more expensive. These figures would make it appear that the Lake Superior district is no exception to the rule that all mining areas are exhaustible. However, the region still has large resources of lower-grade ores which can be concentrated to a higher percentage of iron content, so as to make them shippable. There are also very extensive deposits of taconite rock, which can be crushed and further treated before shipment so as to be made into "pellets" with a higher iron content. In recent years much money has been invested in treatment or "beneficiation" plants, and the share of beneficiated ore shipped from the region has greatly increased, while that of direct-shipping ore has declined. It remains to be seen, however, how well the beneficiated ores from the Lake Superior region will be able to compete with the high-grade ores that can be obtained elsewhere, and whether the cost of beneficiating plants may not ultimately raise the cost of steel to the consumer.

The western district. The western district includes all states from the Missouri river to the Pacific coast. Within that vast area the principal iron-ore producing states are Utah and Nevada, although ore is produced in varying amounts in other states. A major source lies north of the Pine Valley Mountains and west of Cedar City in southwestern Utah.

Iron-ore production and imports in the United States. Production of so-called usable ore, i.e., direct-shipping ore, concentrates, pellets, etc., in the United States

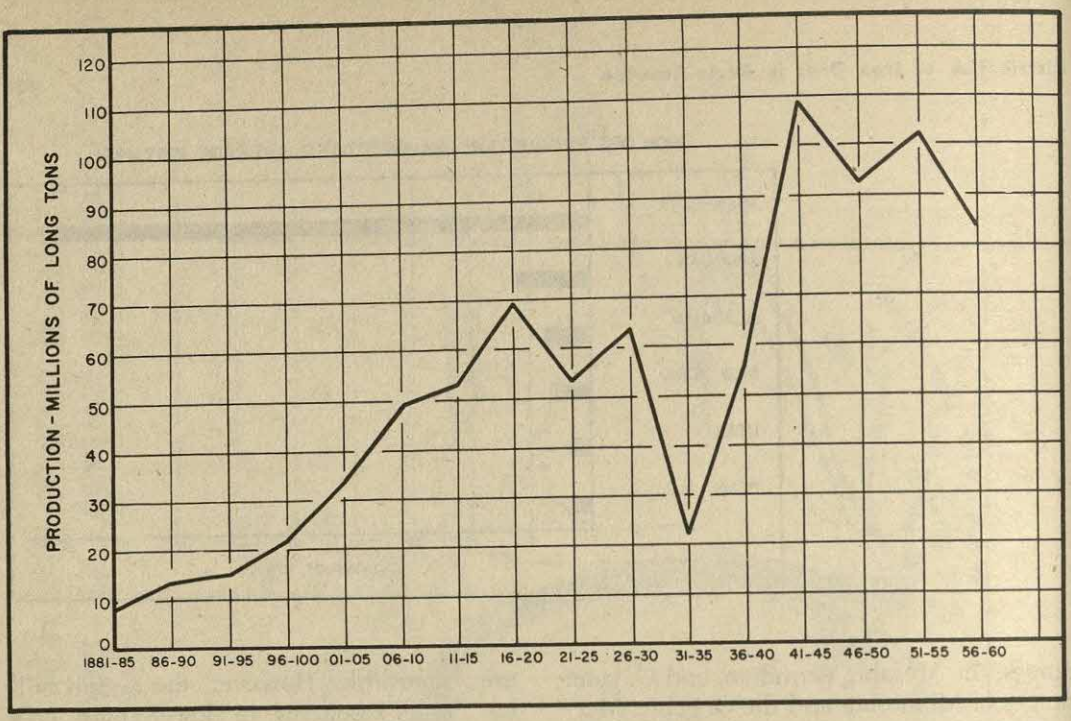
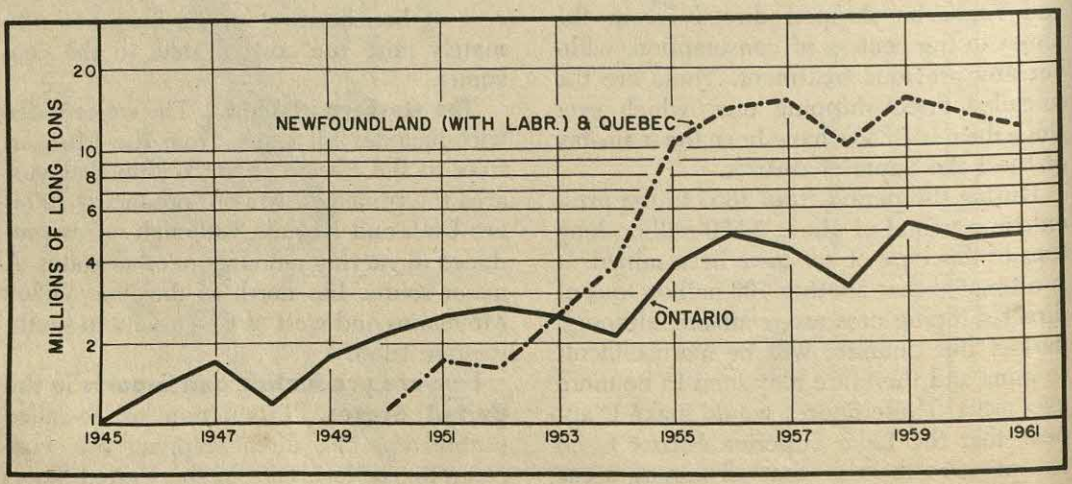


Fig. 288. Production of iron ore in the United States by five-year averages. This is not a semi-logarithmic or "trend" graph. Note the low during the Great Depression, and the two war peaks.

may differ considerably from year to year. In general, however, production varies around about 90 million long tons. Imports in recent years have increased considerably and may well attain the level of about half of domestic production. Canada, Venezuela, and Liberia are the principal suppliers, after which come Chile, Peru, and Brazil (Fig. 288).

Canada. In Canada numerous iron-ore deposits are known in the Quebec, Newfoundland, and Ontario portions of the Canadian Shield, a fair number in western British Columbia, a few near the Alberta-

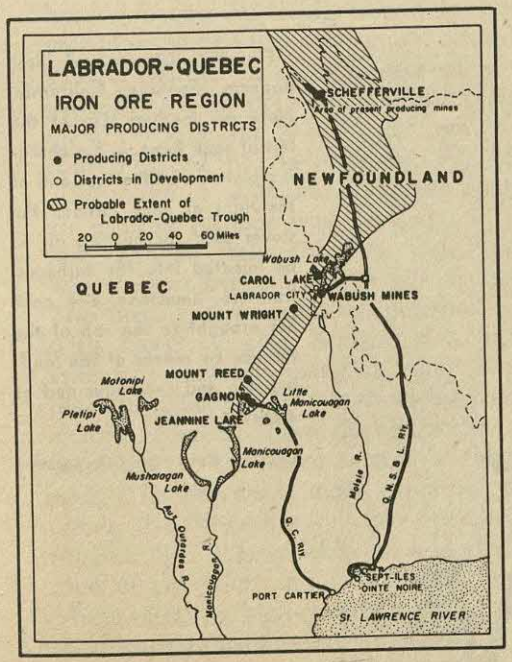
Fig. 289. Annual production of iron ore in the major Canadian districts. The increase in production of the Newfoundland and Quebec districts is due largely to the development of the Labrador fields.



British Columbia border, and at least one major one in Newfoundland. The latter has been in exploitation since before 1900, and because of its location near St. John's it has been an important exporter. Another area that has been worked for a number of decades is the Jamestown district on the northeast shore of Lake Superior, while a more recent development is at Steep Rock Lake, northwest of Port Arthur and Fort William. By far the most important deposits, however, have been found in central Labrador, partly in the province of Quebec and partly in that of Newfoundland. They begin in the Labrador wilderness, some 320 miles north of the little town of Sept Iles or Seven Islands on the lower St. Lawrence river. From Sept Iles a railroad has been constructed to the Knob Lake area, where the new town of Schefferville was created. Production began in 1954 and has increased rapidly since that date. The ore is mined in open pits, and annual capacity is about 15 million long tons. Other developments are in the same general area: on Lake Wabush, in the Mount Reed and Mount Wright areas, and near Lake Jeannine. For the latter a 193-mile-long railroad has been constructed northward, beginning at Port Cartier which is located about 30 miles west of Sept Iles. Also in these regions annual production capacities are large, though some of the ores require beneficiation. The creation of the St. Lawrence Seaway, of course, is of great benefit to the transportation of these ores. Iron-ore production in British Columbia is comparatively small (Figs. 289, 290).

Canadian exports go mostly to the United States, with smaller quantities going to the United Kingdom, West Germany, Japan, and the Netherlands.

Figure 290.



EVOLUTION OF IRON AND STEEL MANUFACTURING

Iron is obtained by means of a simple chemical reduction of iron-oxide compounds. In essence, the common ores, such as hematite, magnetite, etc., are heated together with a suitable reducing agent, such as charcoal or coke, which combines with the oxygen in the ores, and this results in the production of metallic iron. Iron "smelting" probably did not originate until well after 2,000 B.C., perhaps in what is now Turkey, and was long done in small, primitive furnaces which used charcoal and required manually operated bellows to increase the heat. In this manner, the oxygen was burned out of the ore, leaving a product known as "sponge iron," which was then hammered to improve the quality and to produce desired shapes. It was not until much later that sufficiently high temperatures were obtained to actually melt the iron. Even in the mid-twentieth century primitive iron furnaces are still operated in remote parts of Africa and elsewhere.

In Britain during the eighteenth century there was a change in the fuel used. The wood supply, never large in Great Britain, had been seriously reduced by overcutting, so that ironmakers were pressed to find suitable alternate fuels. The best proved to be relatively high-grade bituminous coals, coals which had a high percentage of fixed carbon and which could be fused into coke by heating and under conditions of limited



Fig. 291. Newly built Port Cartier harbor, Quebec, on the St. Lawrence river. Through this port, and another one a short distance to the east, Sept-Iles, are exported the iron ores of central Labrador.

Courtesy Quebec Cartier Mining Co.

access of oxygen. At first the resulting iron was inferior to that produced using the charcoal method, but difficulties were eventually overcome, and by the early nineteenth century coke had become the dominant fuel for iron smelting in Britain and somewhat later became so in other countries of Europe and the United States.

In our time, the process of ore reduction is carried out in blast furnaces which operate continuously for months at a time. The ore and coke are fed in continuously from above. Also fed in are smaller quantities of limestone or dolomite, which serve as a flux to help combine the impurities in the ore in order to form a slag which floats on the molten iron and can easily be separated from it. A blast of hot air is fed in at the base of the furnace; this increases the heat of combustion of the coke, facilitating the reduction of the ore. Molten iron is tapped off at the base of the furnace at intervals. Large blast furnaces produce 2,000 tons of iron a day, or over 60,000 tons per month. The iron produced by the blast furnaces is called "pig iron." Pig iron, however, ordinarily contains from 3 to 5 per cent carbon as well as varying amounts of other impuri-

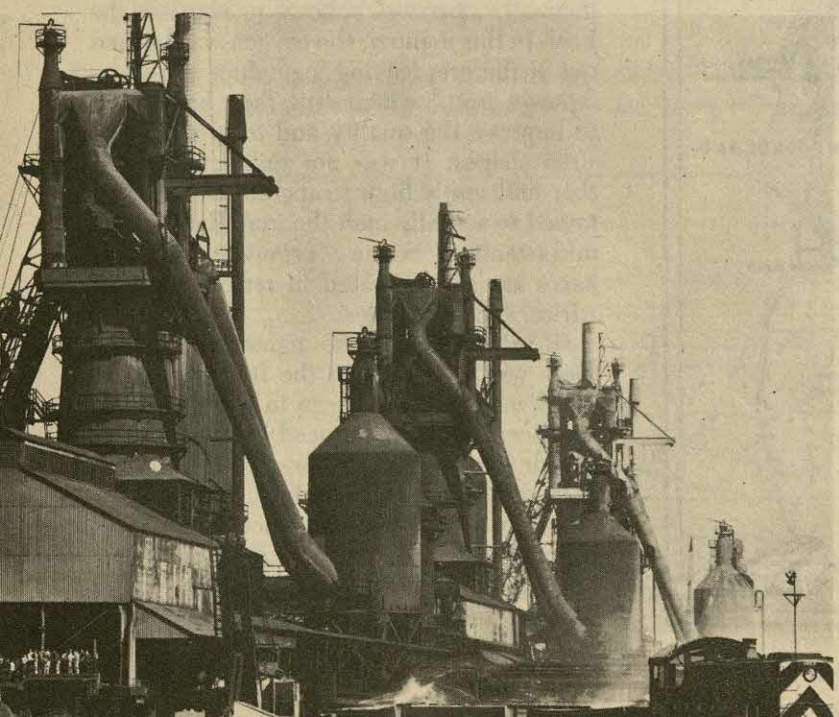


Fig. 292. Close-up of blast furnaces, Fontana, California. Note the loading skip at the left of each furnace, the charging platform at the top, and at the right of each furnace the stoves used for heating air to be injected into the furnaces. Iron ore, limestone, and coke are brought to the top of the furnace by means of the loading skip and there dumped as a charge.

Courtesy Kaiser Steel Corporation

ties. The metal must be purified, a process that involves oxidation of the impurities, thus leaving nearly pure metallic iron. The adjustment of the composition of metallic iron is made through the introduction of fixed proportions of desirable hardening materials, among which carbon is still the most important; the resulting product is steel (Fig. 292).

These three essential procedures may be accomplished in various ways. In 1856 Bessemer devised a vessel with a sandstone lining arranged in such a manner that air under high pressure could be blown through the molten iron from the bottom. The heat given off by the molten iron raised the temperature of the introduced air to the point where it would oxidize such impurities as carbon, manganese, or silicon. This operation, known as the Bessemer process, was improved in 1878 by use of a limestone lining which made its use practical for ores of a higher phosphorus content than was originally possible.

In 1857-59, however, Siemens devised the open-hearth furnace wherein the processes of converting pig iron to steel could be carried on at a slower rate and could be more carefully controlled than was possible with the Bessemer furnace. At first the open-hearth furnace used pig iron only, but it was soon learned that scrap could be added. This constituted a great improvement because in the modern steel industry scrap metal accounts for 40 to 60 per cent of the charge placed into the furnaces (Fig. 293).

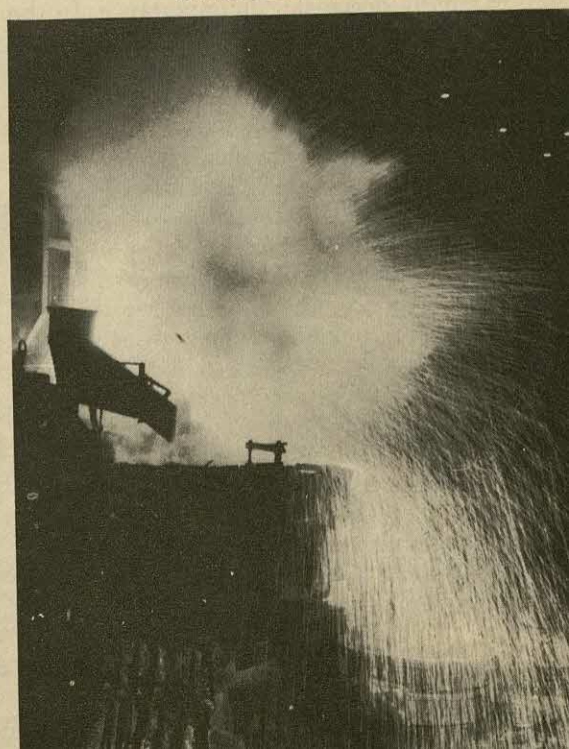
Near the close of the nineteenth century an electric furnace was devised and was first used in Italy, Sweden, and France, where cheap hydroelectricity was available. The furnace is a rounded steel shell lined with basic or acid heat-resistant bricks known as refractory material. Temperatures reaching 3,000°F. are obtained by passing electric currents through electrodes suspended from the upper section of the furnace. The process is more expensive than either the Bessemer or the open-hearth process, but it is capable of a higher degree of precision and is therefore prized where uniform, high-quality steels of exact specifications are needed.

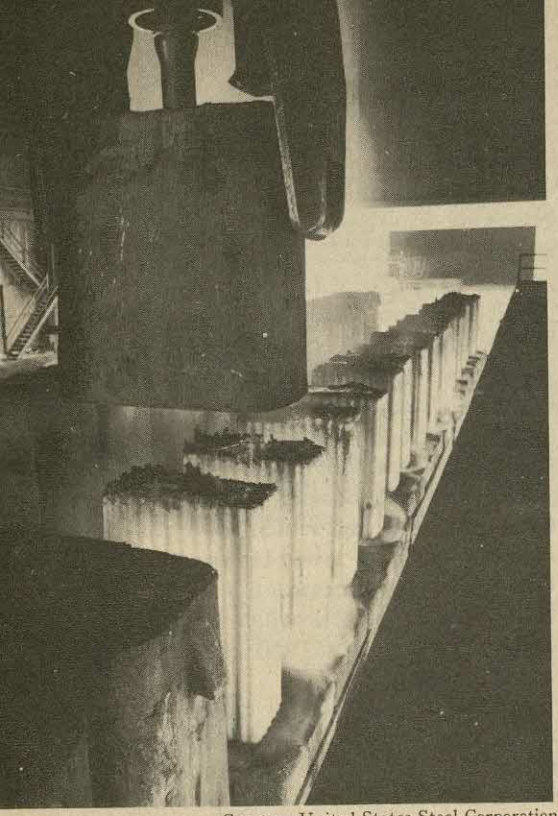
There were few important changes in the major steelmaking processes during the first half of the present century. Then improvements in open-hearth furnaces enabled operators to produce a "heat" of steel in 6 to 8 hours in place of the previously standard 12 to 15 hours. This made it possible to nearly double steel production from existing open-hearth furnaces after some necessary modifications. The modifications consist of the use of oxygen "lances" which speed operation, plus the use of furnace linings which will withstand the higher temperatures generated and which will outlast those formerly used for lower-temperature operations. A further innovation has been the use of oxygen converters which produce steels quickly, at low cost, and to fairly precise specifications.

In the United States open-hearth furnaces account for by far the largest part of the steel produced, usually somewhere between 85 and 90 per cent. Second in importance are electric furnaces with about 6 to 9 per cent. After that come the oxygen-converter or basic-oxygen process and,

Fig. 293. Tapping of molten steel from an open hearth steel furnace.

Courtesy United States Steel Corporation





Courtesy United States Steel Corporation

Fig. 294. The molten steel is poured into molds to form steel ingots. Here, after some cooling, the molds are stripped off by a powerful crane. The ingots will be reheated before they go to the rolling mill.

finally, the old Bessemer process. The latter is rapidly decreasing in importance. In the early 1960's the production of 1 ton of pig iron in the United States required about 1.7 tons of metalliferous materials (ore agglomerates, scrap, etc.), about .75 tons of coke and .25 tons of fluxes. Further fuel supplies are, of course, needed for the manufacture of steel and for the rolling of the steel (Figs. 294, 295).

Importance of scrap iron and scrap steel. Raw material for blast furnaces and steel plants includes scrap iron as well as pig iron. About one third of the world's steel is made from scrap; in some countries that are weak in iron ore, for example, Argentina, Japan, and some of the Mediterranean countries, the furnaces depend largely upon scrap. In the United States scrap is ordinarily the source of half the output of steel. While scrap is gathered from every state, Pennsylvania, Ohio, and Indiana, the major steelmaking states, produce most of it. Blast furnaces use only small quantities of scrap, the open-hearth steel furnaces being by far the largest consumers. Their proportional percentage holds fairly steady at around 65 to 70 per cent of the total, with electric furnaces using 7 to 10 per cent, and Bessemer converters using comparatively small quantities of scrap.

Scrap has long played an important role in steel manufacture. It serves to stabilize prices. When scarcity threatens, iron and steel prices rise, and with them the price of scrap. In the early postwar period, 1945-48, rising prices put dollar values into iron scrap heaps over the nation and thus gave an economic incentive for collection. The driver of the junk-collecting truck became, in a sense, a member of the metallic aristocracy. The reuse of the metallic resources as scrap iron (mostly scrap steel) is a conservation measure of great significance.

Localization of the iron and steel industry. Not so many decades ago, when coal, coke, and fluxes were the main other raw materials used for transforming iron ore into steel, the total amounts of such materials needed generally well exceeded the amount of high-grade iron ore required for the manufacture of one ton of steel. Thus, the iron and steel industry tended to establish itself near deposits of coal, particularly of good coking coal. Naturally proximity to market was also an important factor. An arctic island with plenty of coking coal and ore would hardly be an attractive spot for the establishment of an integrated steel plant.[1] On the other hand, regions such as the Pittsburgh area and the Ruhr coal basin, having excellent market locations, did become major centers of iron and steel production.

Improvements in processes gradually reduced the amount required of raw materials other than iron ore, and location of the industry thus has become much less dependent upon that of suitable fuels, provided cheap transportation, particularly water transportation, is available. Thus, at pres-

[1] An integrated plant is one which combines blast furnace(s), steel furnace(s), and a rolling mill.

ent, a location to which ore and fuel can be brought cheaply, and close to market, may be completely satisfactory for an integrated plant. Examples of successful locations of this type are the American Sparrows Point plant near Baltimore, located on Chesapeake Bay, and the Dutch plant at IJmuiden, located on the coast west of Amsterdam. The former has easy access to coal by rail and to imported ore by water, the latter can bring in all raw materials by water.

Now in pilot-plant stage are processes to produce steel directly from ore, without going through the blast-furnace stage; these processes not only show promise of being able to produce steel from the ore at lower cost, but they would also tend to make the industry even less dependent upon easy access to coking coal. As a result, access to market might well become by far the most important factor in determining the location of steel plants.

THE IRON AND STEEL INDUSTRY OF ANGLO-AMERICA

Iron ore has been mined within the present borders of the United States since the beginning of the colonial period. The earliest colonists keenly felt the need for local iron supplies, as transportation across the Atlantic was slow and long. The New England ores were mostly bog-iron deposits, a form of low-grade limonite, but they sufficed for the operation of numerous small smelters. As a result of such local development, by the end of the seventeenth century New England boasted a sizeable iron industry. The output was used for the manufacture of iron fittings for ships, agricultural implements, builders' hardware, and iron kettles, some of considerable size. The latter were indispensable to the colonial household for cooking, rendering lard, and making soap. However, demands were not large because wood was then the material most used in the construction of ships, implements, homes, and business structures.

The spread of the Industrial Revolution to the New World in the early nineteenth century greatly increased the need for iron products. The small deposits of low-grade iron ore soon proved inadequate to meet expanding demand, and under the pressure of need exploitation of the richer deposits of magnetite found in New York and Pennsylvania began. Numerous iron and steel plants developed there and in Maryland, thus making that section the chief center of the iron industry of the United States. Dur-

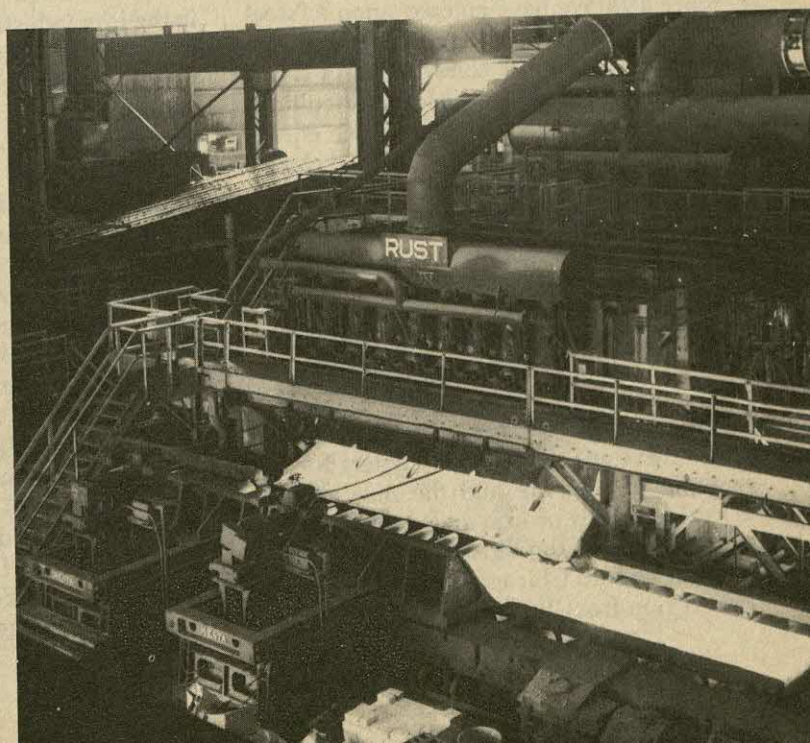


Fig. 295. A slab of steel has been reheated in the furnace marked "Rust IV." The slab moves over rollers toward the right, and will be reduced by other machinery to a thickness of 3/16 inches, and a length of 1500 feet.

Courtesy United States Steel Corporation

ing the early stages of this development charcoal was the major smelter fuel, but with diminishing supplies of wood for charcoal it was found that anthracite also could be used; thus the anthracite deposits contributed substantially toward making eastern Pennsylvania the leading center of the iron industry until after the Civil War. By 1860 American mills were turning out over 200,000 tons of iron rails per year. The development of the West created great markets for iron and steel products, and coke made from the bituminous coal of western Pennsylvania was soon found to be cheaper and better than anthracite for ironmaking and steelmaking. These factors caused the center of the iron industry to move westward again, from eastern Pennsylvania to across the Alleghenies. Pittsburgh became the nation's "iron and steel capital," a position it still holds in the public mind.

Measured by present standards, growth was slow until after 1880. In 1879 the total amount of iron ore mined in the United States was only 6,308,000 tons. The increase in production of iron and steel began with the shipments of ore from the head of Lake Superior. By 1890, as a result of their low cost the ores from this source had attained dominance in the American iron and steel industry (Fig. 288).

Since 1890 we have entered upon a "steel age." Wood has been almost entirely displaced by steel in the construction of ships, railway cars, motor vehicles, agricultural machinery, and all kinds of factory equipment. Skyscrapers have a steel skeleton, and even office equipment is now made largely of steel. In every important industry steel is an essential.

IRON AND STEEL CENTERS OF ANGLO-AMERICA

The United States. In the United States there are a few major centers for the smelting of iron ore and the manufacture of various kinds of iron and steel, the foremost ones being the Pittsburgh-Youngstown and Gary-South Chicago districts. The Lake Erie region from Buffalo to Detroit may be considered as an extension of the Pittsburgh-Youngstown district, since the two have many factors in common. Taken together, the output of iron and steel from these plants on or near Lake Erie and from those at the head of Lake Michigan constitutes by far the major part of the production of the United States (Fig. 296).

Iron-ore transportation in this country is dominated by the Great Lakes water route and the St. Lawrence Seaway, supplemented by short rail haulage from the lake shores to the smelters. Water transportation is cheap, and therefore, even though distances are relatively great, ore is available at low cost for the coal of the Pittsburgh-Youngstown district and of Illinois. The importance of the Great Lakes can hardly be overemphasized in accounting for the prominence of the great iron-manufacturing cities from Pittsburgh and Buffalo in the East to Chicago in the West (Fig. 286).

THE PITTSBURGH-YOUNGSTOWN DISTRICT. The leadership of the Pittsburgh-Youngstown area must be attributed, however, to several factors in addition to inexpensive lake transportation. The early start of the area gave an initial competitive advantage, which is a factor of continuing importance. Prior to the exploitation of Lake Superior ores, Pittsburgh had achieved prominence in the iron industry through utilizing nearby ores. The bituminous coal of the area was found to make coke of excellent grade, and abundant natural gas near at hand furnished the cheapest, most efficient fuel for steam purposes.

The rapidly expanding markets created by the agricultural development of the Midwest were another important factor tending to promote the growth of the steel industry in this region and enabling it to overtake the iron and steel industry of eastern Pennsylvania. Compared with newer steel centers farther west, such as Toledo, Gary, and South Chicago, Pittsburgh still has some advantages in her nearness to the great eastern markets. This, combined with her early start, has retained for her a position of supremacy in the face of keen competition. The Pittsburgh-Youngstown district ranks as one of the greatest iron-smelting and

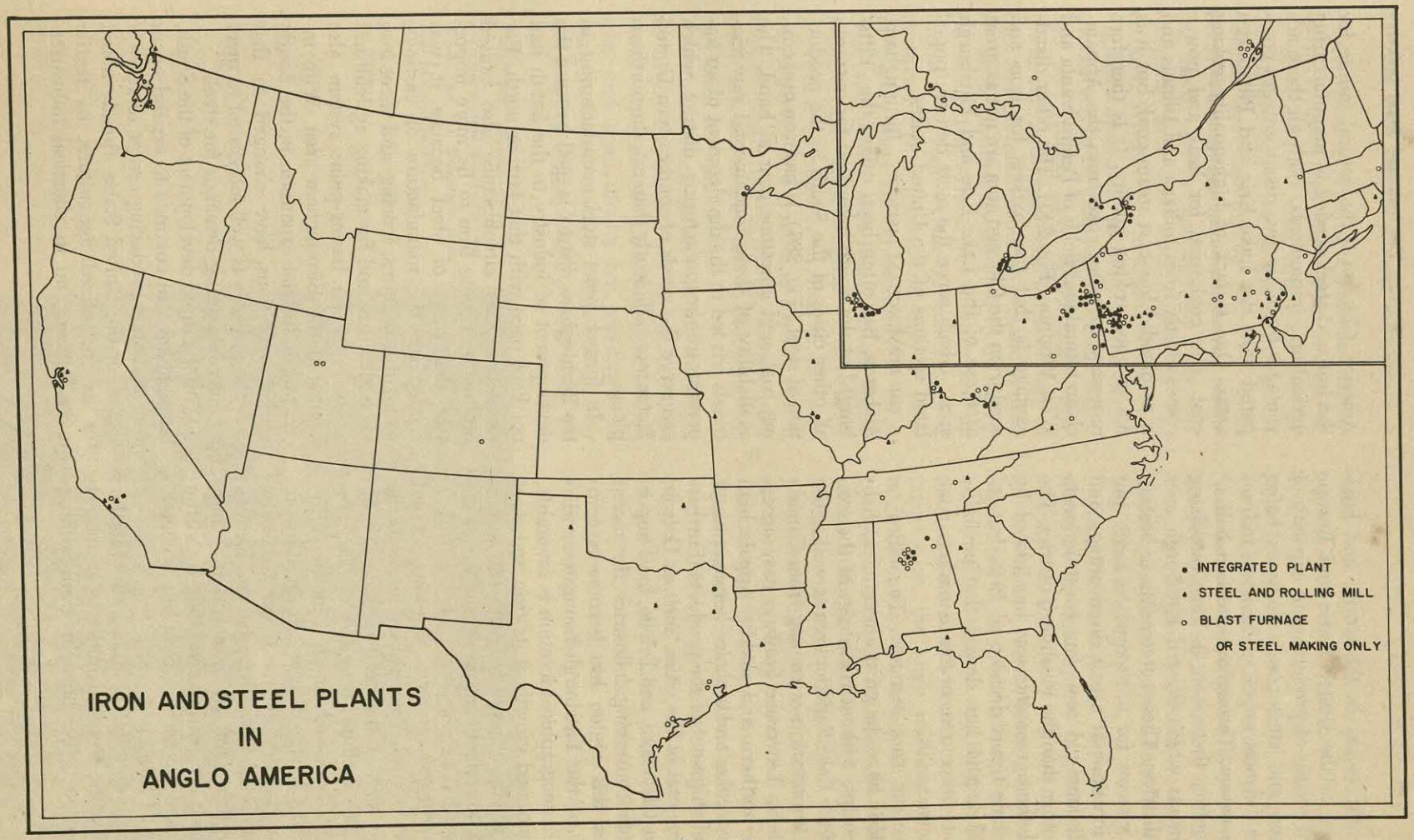

IRON AND STEEL PLANTS
IN
ANGLO AMERICA
INTEGRATED PLANT
STEEL AND ROLLING MILL
BLAST FURNACE
OR STEEL MAKING ONLY

Figure 296.

steel-mill centers in the world, and businessmen of the United States and Europe view the ratio of production to capacity of the iron and steel plants there as being among the most important business indexes of the nation. Throughout the first half of this century there were in force rate-fixing agreements which favored Pittsburgh over other districts. These agreements, or basing-point systems for transportation rates, put other locations at a cost disadvantage and thus discouraged new plant construction in areas other than the Pittsburgh district. The last of the agreements was invalidated by a Supreme Court decision of 1948, but industrial inertia has slowed the inevitable moves to other areas nearer to markets, coal, or raw materials.

THE LAKE ERIE DISTRICT. The cities on Lake Erie have the great advantages of direct receipt, without reloading, of the iron ores of the Lake Superior area as well as the newly important ores coming from Canada via the St. Lawrence Seaway; easy access to the northern and middle Appalachian coal and coke; and a choice between water and rail shipment of the products. Furthermore, several of the cities, such as Detroit, Buffalo, Cleveland, and Toledo, have important steel-consuming industries. In recent decades this region has become a competitor of the Pittsburgh-Youngstown district. Its geographical location is favorable, and continued growth of its iron and steel industry may be expected with the expansion of the steel-consuming industries on and near Lake Erie.

THE CHICAGO DISTRICT. Ranking second to the Pittsburgh-Youngstown district is the Chicago area at the head of Lake Michigan, which includes the cities of Gary, Indiana Harbor, and South Chicago (Fig. 286). The Chicago district is favored by ore cheaply available via the Great Lakes, by low-cost coals from the adjacent Eastern Interior field, and by great interior markets which are readily accessible by virtue of the extensive network of railroads centering upon Chicago.

The recent growth of cities in the interior has called for large quantities of structural steel. Seated in the heart of grain-farming America, Chicago is the natural source for the iron and steel needed in manufacturing agricultural implements. With all these advantages there are two disadvantages compared with the Lake Erie and Pittsburgh areas. One is lack of high-quality coking coal. The coal used for heat and power comes mostly from Indiana and Illinois and is a splendid low-cost steam coal, but it is not of good coking quality. It is therefore necessary to bring coke from the Appalachian bituminous fields of Pennsylvania and West Virginia (Fig. 240). The other disadvantage is that the markets for iron and steel from the Chicago area are not as great as those of the Lake Erie and Pittsburgh areas, which serve the most densely populated sections of the United States.

THE BIRMINGHAM DISTRICT. Birmingham, Alabama, has often been called the "Pittsburgh" of the South because it far outranks all other cities of the South in the production of steel (Fig. 286). It has iron ore, coking coal, and limestone near at hand. The availability of these fundamental raw materials has led to the development of an important iron-manufacturing district which can serve the needs of southeastern United States more efficiently than can the northern plants.

In former years steel manufacturing in the Birmingham district lagged because the development of industry in the South had not kept pace with that farther north. For some time this circumstance also caused production of pig iron to be more important than that of steel because it was needed for the manufacture of castings, wrought-iron forms, fencing, and sheet iron for agriculture and for making agricultural machinery. The basing-point system also hampered the Birmingham area. With increasing industrial expansion in the South, market conditions have changed so that now the industry is well integrated to meet the ever-increasing demands for steel.

With the rapid development of the South, Birmingham will continue to expand as an iron- and steel-producing center to serve a section of the United States already noted for its specialized agriculture, its textile manufactures, and its chemical industries.

THE EASTERN PENNSYLVANIA-MARYLAND DISTRICT. Although the major centers of the steel industry have long been west of the Alleghenies, some of the older eastern districts have maintained important positions. When anthracite was the chief smelting fuel, eastern Pennsylvania was the foremost iron and steel center in the country. When coke from bituminous coal displaced anthracite, and the Pittsburgh district forged to the front, the established iron and steel plants near Harrisburg, Allentown, and Bethlehem found it necessary to turn to high-quality specialty manufactures, a field of business that proved to be highly profitable. High-grade ores are furnished by the mining areas of the Adirondacks and northeast Pennsylvania, and only a comparatively short haul is necessary to bring coke and coking coal from western Pennsylvania and West Virginia. The densely populated territory from Boston to Richmond serves as a front-door market of first magnitude for quality steels ranging from steel rails and armor plate to the finest cutlery steel for razor blades.

With the recent advent during the 1950's of large-scale importation of iron ore from South America and Canada, an additional iron and steel district has developed in Maryland and eastern Pennsylvania near the head of Chesapeake Bay and along the estuary of the Delaware river. The best-known centers are at Sparrows Point, Maryland (near Baltimore), the world's largest steel plant, and at Morrisville, Pennsylvania, on the Delaware river, opposite Trenton, New Jersey. This district is strategically situated to receive shipments of ore from Chile, Brazil, and Venezuela, as well as the recently developed iron-ore deposits of Quebec, Canada (Fig. 297).

The tidewater plants represent a new phase in the localization of the American iron and steel industry. To the extent that the United States may become increasingly dependent upon imported high-grade ores, tidewater locations in the East, and probably elsewhere, will have locational advantages. Also, the large seaboard cities, in addition to their attraction in terms of low-cost water transport for ores and coal, constitute major markets for steel products.

OTHER DISTRICTS. The city of Pueblo, Colo., has the distinction of being the oldest iron-ore smelting center and steel plant west of the Mississippi river. Ore used in Pueblo is mined in southwestern Wyoming, where a high-grade hematite occurs in fairly large quantities, and good-sized quantities of ore have in recent years been shipped from southern Utah to Pueblo. Coking coal is obtained from the nearby Raton Mesa field on the Colorado-New Mexico border

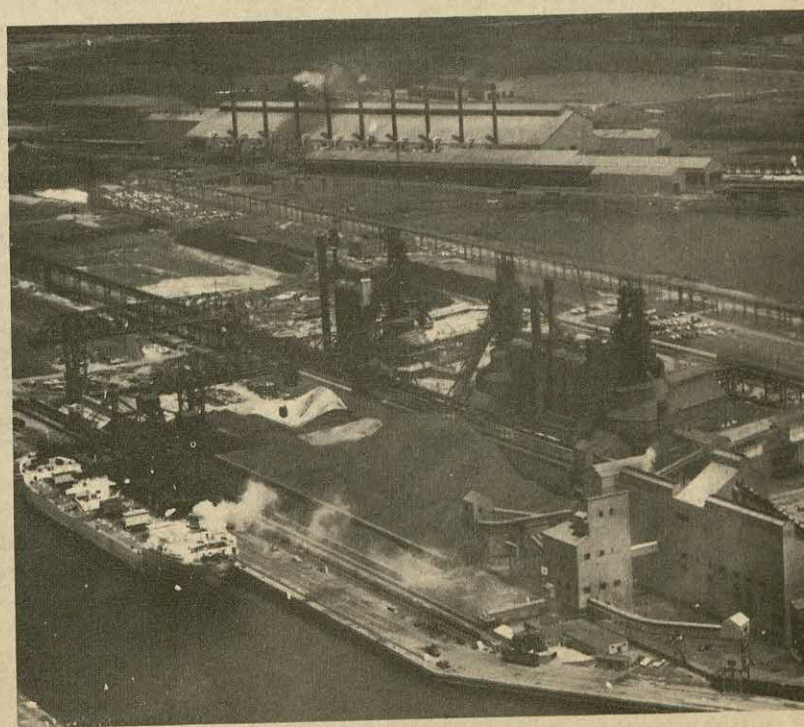


Fig. 297. General view of a modern steel plant, Fairless Works, on the Delaware river near Morrisville, Pa.

Courtesy United States Steel Corporation

immediately to the south. In Utah there is a steel plant south of Salt Lake City. Because of the available reserves of coking coal and accessible good-quality iron ore, coupled with the growing markets of the Rocky Mountain area, the two districts can be expected to maintain their place as producers of iron and steel (Fig. 296).

On the West Coast there are several steel-producing centers of considerable importance to that part of the country, although production constitutes only a comparatively small percentage of the United States total. They are the Los Angeles, San Francisco, Portland, and Seattle districts. In all of them steel scrap is the principal raw material for direct production of steel by means of electric furnaces and open-hearth furnaces. Production from ore via the blast furnace exists only near San Bernardino in the Los Angeles district. Fluxes and small amounts of iron ore are available locally, and the latter can be brought in also by sea. Fuel oil and natural gas are readily available in California, and oil products can be easily brought to the Northwest. While there were numerous small plants for the conversion of pig iron and scrap into structural forms needed in industry and for construction purposes, until very recently no integrated iron and steel plants existed west of the Rockies. With the expanding industrial development characteristic of the Pacific coast states, steel plants in suitable locations should find a growing market for their products (Fig. 296).

Canada. In Canada the iron and steel industry is located primarily in Ontario, with large integrated plants at the head of Lake Ontario and at Sault Ste. Marie, both of which have easy access by water to the ores of the Labrador peninsula and those north of Lake Superior. Next in rank is Nova Scotia, with an integrated plant at the Atlantic port of Sydney in northern Nova Scotia which utilizes iron ores from St. John's (Wabana) in Newfoundland, and with smaller plants elsewhere. Other iron and steel plants are located in the Montreal region. The western provinces of Canada have a small, though locally important, iron and steel production.

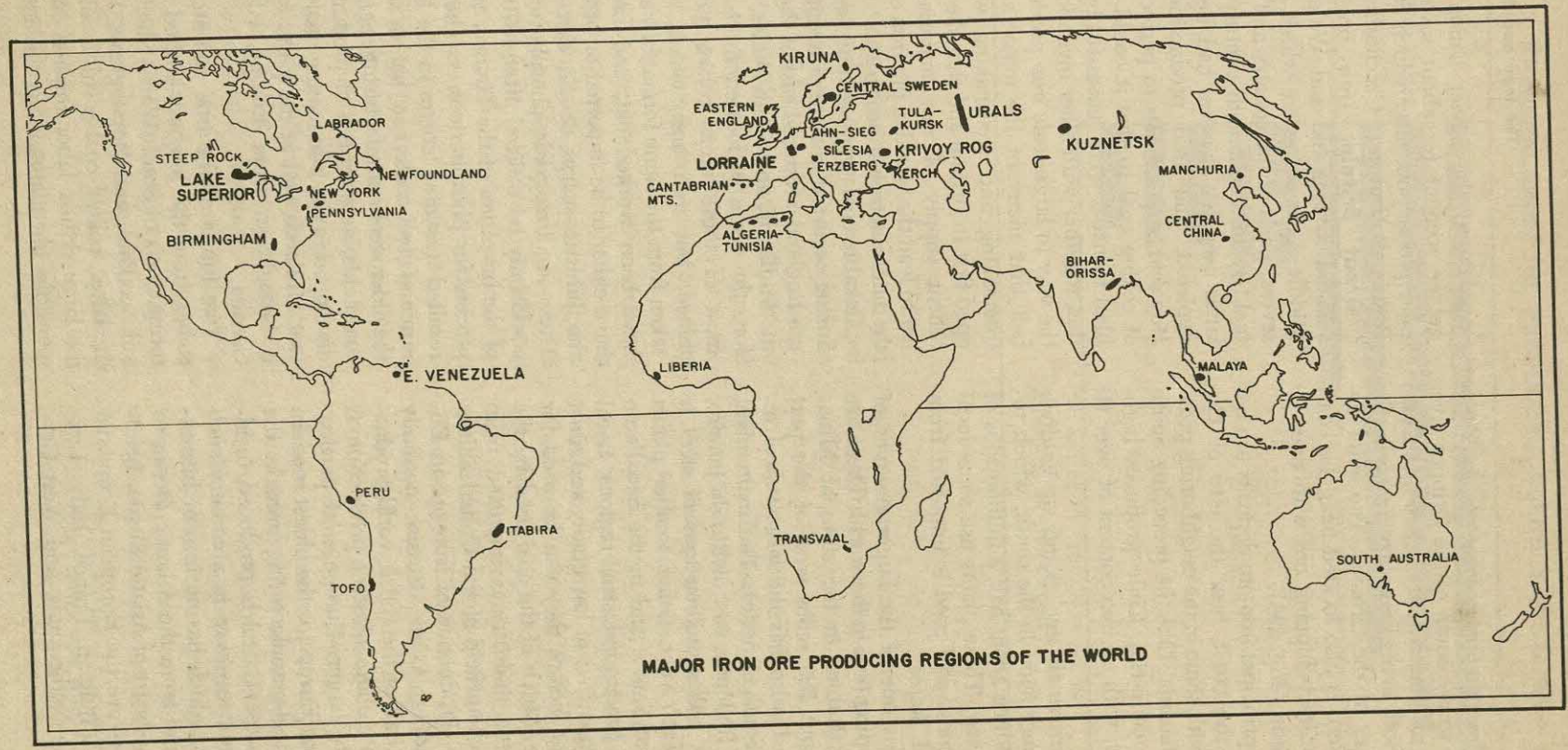
IRON-ORE RESOURCES AND STEEL INDUSTRIES OF OTHER PARTS OF THE WORLD

Large reserves of iron ore are found on all continents. The immense increase in volume of ore mined has taken place since low-cost steelmaking processes were developed a century ago. In most of the nations with a long history of quantity steelmaking, supplies of high-grade, direct-shipping ores are limited. In several of these nations lower-grade ores are now being mined, and imports are on the increase. In recent decades there has been a rapid development of new iron-mining districts in areas remote from the major industrial regions of the world, not only in Canada, but also in South America, Africa, and elsewhere. In many of these areas exploitation is limited to deposits of high-grade, direct-shipping ores located comparatively close to seacoasts. Steel industries, which half a century ago were largely restricted to the countries of Europe and Anglo-America, are now developing in many other countries. World steel production increased from less than 200 million tons in 1950 to about 400 million in the early 1960's.

Latin America. South America has a number of high-grade, easily mined iron-ore deposits with large reserves but few, and relatively small, steel plants. The major impediments to the development of a large steel industry are lack of suitable coal and the, as yet, small internal market.

Iron ore has been produced for many years in Cuba and Mexico, but the output has been small. Mexico has small steel plants, among others one at Monterrey.

Since 1950 important changes have occurred in iron-ore mining within South America. Venezuela, which only started production in 1950-51, now produces about 20 million tons of iron ore per year. Peru started production as late as 1953 and now produces about 7 million tons per year. In both cases the ore is high-grade direct-shipping ore (63 to 65 per cent iron), and the mines are located near the coast. The bulk of these ores are shipped to the United



MAJOR IRON ORE PRODUCING REGIONS OF THE WORLD

Figure 298.

States. The two major locations in Venezuela are to the south of the Orinoco river in the Sierra Imataca, at El Pao and Cerro Bolívar. Both areas have easy access to the sea by way of the Orinoco. The chief deposit in Peru is also located near the coast and is a direct-shipping ore with over 60 per cent iron (Fig. 298).

Chile's principal iron-ore deposits are not far from the coast, near the city of Coquimbo, with some in the neighboring province of Atacama. Like the preceding South American countries, Chile produces high-grade ores, with an iron content of over 60 per cent.

There are small steel plants at Valdivia and at Concepción in the south, which together produce about half a million tons of steel per year. These plants use some local coal, but most coal used is imported from the United States.

Brazil has one of the larger reserves of direct-shipping ores in the world. These are located at Itabira in the state of Minas Gerais, about 200 miles west of the port of Vitória. It also has the largest steel industry in South America. The main plant is at Volta Redonda, east of Rio de Janeiro, where over half a million tons of steel is produced each year. Other smaller plants are found at Santos and in the São Paulo and Rio de Janeiro industrial regions. Local coals are expensive, of low grade, and must be processed before they can be used for cokemaking. Much of the coal used by the Brazilian steel industry is imported from the Appalachian field of the United States.

Europe. Production of iron ore in Europe, including Asiatic Russia, normally amounts to half of the entire world production, and the share of steel production is even slightly larger. Europe, and particularly Western Europe, is the oldest modern iron- and steel-manufacturing area in the world. At present steel is produced in almost all countries—even in a country such as Denmark, which has no iron or bituminous coal—and from the Atlantic Ocean to deep into the heart of Asiatic Russia. Leading producers are the European Economic Community (Belgian, France, Italy, Luxembourg, the Netherlands, and West Germany) and the Soviet Union, which together account for about seven tenths of total production, after which follow Great Britain, Poland, and Czechoslovakia.

Great Britain. Iron ore has been smelted in England and Wales since the Middle Ages, using ore which occurred in several parts of the country and charcoal as fuel. By the eighteenth century the woodlands used for charcoal had been severely depleted, and iron production declined. However, experiments to perfect a method of coking coal so that it could be used in blast furnaces were successful by 1740, and this, together with other inventions, opened the way to large-scale iron production. The fact that many of the major advances in ironmaking and steelmaking were developed first in Britain and that she had an excellent supply of raw materials allowed her to lead the world in pig-iron output until the late nineteenth century.

Cokable coal, iron ore, and limestone for fluxing occurred in close proximity in northern England, west and east of the Pennines, the Midlands, and South Wales, and therefore the industry located there. Today in most of these areas coking coal is still mined, but iron ores, which were often taken from the same formations as the coal, have been worked out, and ore supplies have either to be imported or brought from the Jurassic scarps of the east Midlands. These are low-grade phosphoric ores and could only be utilized after 1870, the date of the invention of the Thomas or Gilchrist process for phosphoric ores. Their use has resulted in some changes in the location of iron and steel centers so that, in addition to the older steel-manufacturing regions on the coal fields, new centers of production have developed in the iron-mining districts of the east Midlands and at the ports where iron is brought in from Europe, Africa, and Canada.

Two thirds of the iron and steel output comes from the long-established manufacturing areas of South Wales, Sheffield, central Scotland, and Birmingham. In all but the latter, coking coal is still available; but the large skilled labor force is in part responsible for maintaining the industry in

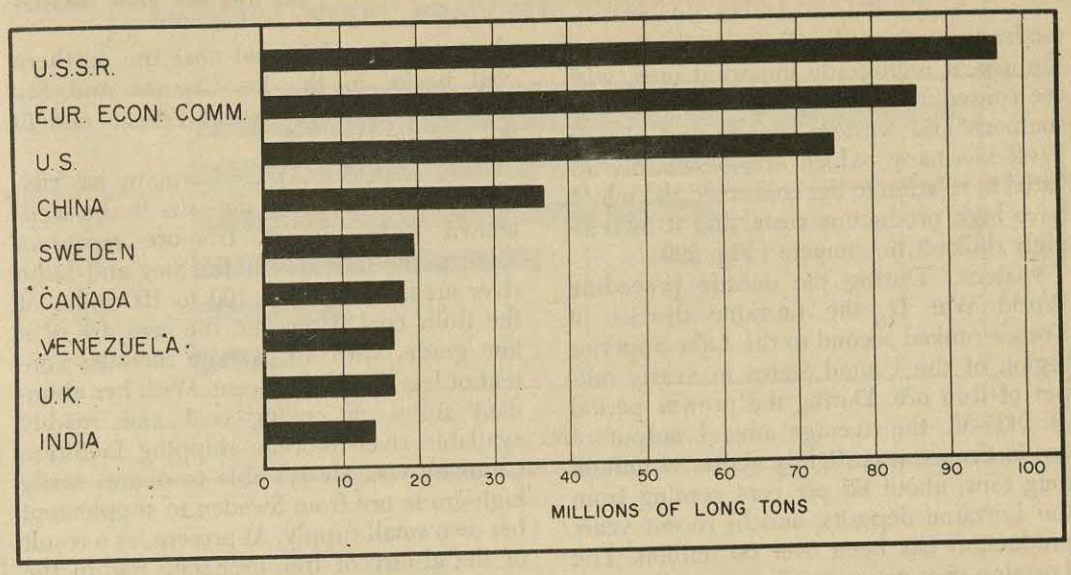


Figure 299.

these traditional locations. In Scotland and Wales government support has enabled large integrated steelworks to be built in an effort to offset unemployment and to utilize the skilled labor available. In the Birmingham district neither ore nor coal are directly available, and steel is made from scrap, pig iron from the east, and coke from the north.

After 1870 some iron and steel manufacturers began to move to the Jurassic ores in northeast England and the east Midlands, and by 1913 the Middlesborough area of northeast England provided two fifths of British pig iron. The nearby Cleveland Jurassic ores are now largely worked out, but it has been possible to maintain the industry, although production has decreased, by means of imported ores because the region is located on the coast. However, the east Midland ore region, part of the same ore belt farther south, today manufactures the bulk of British native pig iron and around 10 per cent of the steel.

Other recent steelworks have been located in ports and close to their markets, notably one at Dagenham near London, which supplies the motor industry, and at Cardiff, South Wales, which supplies the tinplate industry.

In the 1950's British steel output increased from 16 million tons to over 20 million tons a year. There is a tendency to modernize existing steelworks and to develop large integrated steelworks, often associated with another industry. While she will remain self-sufficient in coking coal, Britain will always have to import the bulk of the iron ore.

The European economic community. The High Authority, the European Coal and Steel Community, coordinated production of coal, iron ore, and steel within the member countries and thus became the chief vehicle for the further integration of economies, which led to the creation of the European Economic Community, popularly called the Common Market by Americans. The High Authority still continues to coordinate and integrate the activities in the coal and steel industries of the countries concerned. Free exchange within the Common Market area has led to an unprecedented expansion of steel production and has made possible adjustments in coal mining and other aspects of basic production which were long overdue. Within the Community there is a considerable volume of trade in iron ore, but imports from elsewhere are even larger.[2] There is a definite

[2] In 1961 extraction of ore in the Community was 96 million metric tons, intra-Community trade was 27 million metric tons, and imports into the Community amounted to 36 million metric tons.

tendency within the Community toward the use of high-grade imported ores, with the consequence that certain iron mines in southern and western France and also in West Germany, which are awkwardly located in relation to the consumer and which have high production costs, find it increasingly difficult to compete (Fig. 299).

FRANCE. During the decade preceding World War II, the Lorraine district of France ranked second to the Lake Superior region of the United States in yearly output of iron ore. During the prewar period of 1935-38, the average annual output of ore in France was slightly above 34 million long tons, about 95 per cent coming from the Lorraine deposits, and in recent years production has been over 60 million. The Lorraine ores are not rich in metallic content, averaging only about 33 per cent iron, but as the ores are oölitic, and thus contain calcium carbonate, they can be readily smelted at a relatively low cost. The ores run high in phosphorus, and for a long time they were not considered usable for the manufacture of iron. However, the invention known as the Thomas or Gilchrist process overcame this difficulty and made it possible not only to utilize these ores, but to sell the ground slag, the "Thomas slag flour," as a valuable phosphoric fertilizer by-product. As a whole the Lorraine basin is credited with containing the largest iron ore reserves in Western Europe.

The seizure of Lorraine, including a portion of the Lorraine iron-ore deposits, by the Germans at the close of the Franco-Prussian War of 1870 helped Germany to industrialize at a highly accelerated rate, as the rapid rise of the Rhineland-Westphalian industrial district eloquently testified. In 1913 that area which includes the Ruhr coal basin had become the greatest steelmaking district in continental Europe. After regaining Lorraine in 1918, France was able to become the major ore-exporting country in the world and to further build up its steel industry. At present the Lorraine ores remain within the Community. The major concentration of steel plants in France is in the Lorraine region between Nancy and the Luxembourg border. Other plants are found in and near the northern coal basin, in the Le Creusot and St.-Étienne regions of central France and in the French Alps.

WEST GERMANY. West Germany has rich steam and coking-coal deposits in the well-known Ruhr district. Iron-ore resources occur to the southeast in the Sieg and Lahn river areas and within 100 to 150 miles of the Ruhr coal. However, the ores are of a low grade, with an average metallic content of less than 30 per cent. With her abundant stores of coking coal and readily available river-to-ocean shipping facilities, Germany was always able to obtain easily high-grade ore from Sweden to supplement her own small supply. At present, as a result of the ability of free exchange within the Community, much iron ore comes from France, often with coal as return freight.

West German steel production still centers in the Ruhr coal basin, although plants have shown a tendency to move closer to the Rhine river. A second major center lies in the Saar region, just east of the principal French and Luxembourg steel-producing region. Many small plants occur in the Sieg-Lahn iron region, and others along the upper Rhine in the Mannheim area.

BELGIUM, LUXEMBOURG, AND THE NETHERLANDS. Lying near the great ore deposits of Lorraine are the two small but industrially important countries of Belgium and Luxembourg. The former has coal but hardly any ore, while the latter shares in the Lorraine ore but has no coal.

In Belgium the iron and steel industry is located mostly in the Charleroi and Liége regions; in Luxembourg the plants are in the southern section of the country, forming part of the Lorraine-Saar iron- and steel-manufacturing district.

The Netherlands has coal but no iron ore. It possesses an integrated plant near IJmuiden, at the west end of the North Sea Canal from Amsterdam to the North Sea, the locks of which can accommodate very large sea-going vessels.

ITALY. Iron-ore reserves of Italy are limited, and the steel industry must depend largely on imported ore and scrap. Among the early advanced metal workers were the

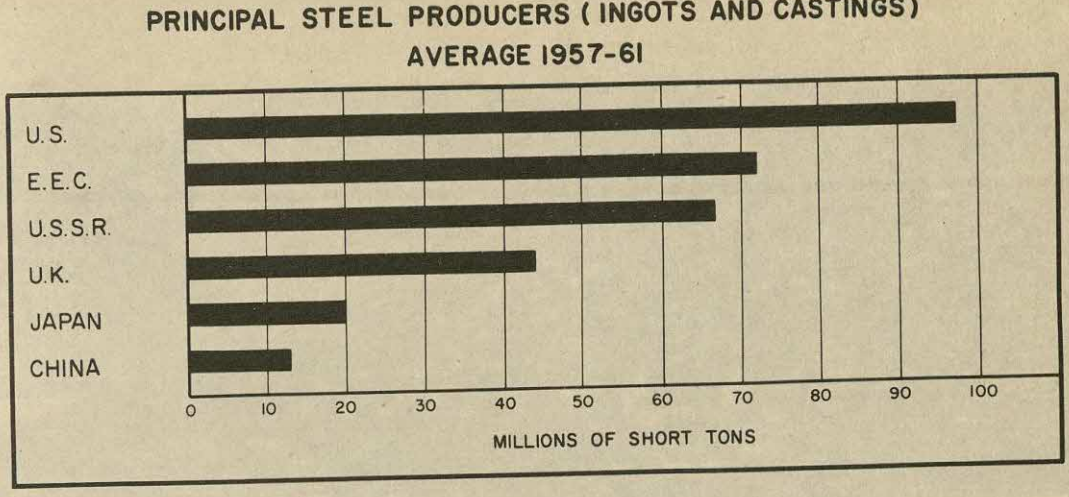


Figure 300.

Etruscans, pre-Roman inhabitants of Italy. Their primitive furnaces did not attain sufficient heat to melt the iron, but reduced or burned out the oxygen in the oxide ores, leaving a sponge iron. The discarded debris accumulated over some centuries of Etruscan ironworking, amounting to over two million tons. In our time this material, containing over 50 per cent iron, has turned out to be useful for blast furnaces on the west coast of Italy. The steel industry in Italy was located primarily in the north, but in recent years, because of the dependence on imported scrap, ore, and coal, new plant construction and plant expansion have occurred at tidewater locations. This is similar to what is taking place in the United States and Great Britain. An example is a new steel plant at Taranto on the southern coast of Italy.

Other European producers. Smaller producers in Western Europe are Sweden, Austria, and Spain. Sweden has long been famous for the quality of her steel manufactures, a fame achieved long before she became known for large ore reserves. The early industries were small-scale affairs using the numerous small ore deposits of central Sweden, with charcoal for smelting. With the high-grade carbon steel, the early Swedish workers produced excellent cutlery, particularly swords, enabling them to develop a reputation for superior quality, a reputation which is still a business asset.

Sweden is known for its great reserves of magnetic iron ore in the far north of the country, in the Kiirunavaara and Gällivare districts beyond the Arctic Circle (Fig. 301). This ore averages above 60 per cent iron. Annual production of the Swedish mines may be expected to range between 18 and 20 million tons, of which about 80 per cent is exported; England, the European Economic Community, and the United States are the principal customers, with lesser amounts being shipped to Poland and other countries.

The Swedish iron and steel industry, located in the central part of the country north and west of Stockholm, is handicapped by the lack of coking coal. This lack is overcome partially by the availability of coal by water transportation from West Germany and England. The extensive forests supply charcoal, which is still used to some extent in the manufacture of high-quality steels.

Austria has good-quality iron-ore resources in the southeastern part of the country, particularly in the general area around the city of Graz. Main industrial centers are Linz and Eisenerz. One of the recent significant innovations in steelmaking, the Linz-Donawitz process, which is the fastest known method of producing high-quality steel, was introduced in Linz.

For centuries northern Spain has been a major source of iron ore for western Europe. Although Spain has a gradually increasing



Courtesy Swedish National Travel Office, New York, N.Y.

Fig. 301. Iron mining in northern Sweden. Part of the town of Kiruna in foreground, Mount Kiirunavaara in background. The terracing is the result of open-cut mining. A very large underground mine is also developed.

production of steel, most of the ore mined is exported.

Russia and adjacent countries. During the eighteenth and nineteenth centuries European Russia was a significant producer of iron, with plants first in the Moscow region and later in the Urals. Charcoal was the major fuel and reducing agent used. At present the Soviet Union is among the three major producers of iron ore and steel, with the European Economic Community and the United States (Figs. 299, 300). Growth has been rapid since the Bolshevik revolution, because of the emphasis placed upon the development of the heavy industries. The steel industry was severely damaged during World War II, when production was reduced to 12 million tons from a prewar maximum of 18 million. However, the rebuilding of the postwar years and new plant construction so increased output that by 1960 over 70 million tons of steel were produced.

The leading iron- and steel-producing area is located in the Ukraine near the Krivoi Rog iron-ore deposits; in the Donbas, or Donets Basin, the coal and industrial area somewhat farther east; and in the Kerch peninsula. Over half of the iron ore and over 30 per cent of the Soviet steel come from these areas. This region was relatively even more important in the years preceding World War II, but was badly damaged. During the war and postwar periods new plant construction was focused on the southern Ural region and the Kuznetsk Basin farther east in Siberia.

The ores of Krivoi Rog and the Kerch peninsula are smelted with the coking coals of the Donbas about 200 miles to the east and north. Major iron- and steel-producing centers within this complex are the rapidly growing Dnieper district; Zhdanov, on the coast of the Sea of Azov; and the Donbas proper.

The Ural Mountains, a north-south mountain range which follows approximately the 60th meridian, are one of the world's principal metalliferous areas. There are large deposits of iron ore (magnetite), plus usable deposits of manganese, cobalt, nickel, chromium, titanium, tungsten, and vanadium. Here are found not only the basic iron ore but the needed ferroalloy metals as well. Of the nonferrous metals copper, aluminum, zinc, gold, platinum, and columbium are mined. Immediately to the west lies Russia's major oil region, but unfortunately the Ural Mountain region itself has little coal beyond lignite.

About a third of Soviet iron ore is mined here, especially at Magnitogorsk in the south, but also at three other deposits farther north, to about the 60th parallel. The Urals are estimated to have about one tenth of Soviet iron-ore reserves.

Over one third of Soviet steel is produced in the Urals using local ores. Coal, however, must be brought in from considerable distances. The two main sources are Karaganda, over 700 miles to the southeast of Magnitogorsk, and the Kuznetsk Basin, or Kuzbas, about 1,200 miles to the east beyond the Ob river. This movement of coal is more rational than it might seem at first sight in that ore is brought to a steel plant at the Karaganda coal deposits. The Kuzbas has become a steel center of major importance, based upon available coal and originally upon iron ore from the Urals. Since World War II large deposits of iron ore have been developed southeast of Novokuznetsk (formerly Stalinsk) in the Kuzbas. The area now accounts for about one tenth of Soviet iron ore and Soviet steel production. The Novokuznetsk steelworks is the second largest plant in the country.

Other deposits of iron ore and coal exist throughout the country. They are, however, widely scattered over the vast territory of the Soviet Union and must be moved great distances before they can be used. One example is the Yena iron-ore deposits of the Kola Peninsula in the extreme northwestern part of the country. The ore is smelted at a steel plant at Cherepovyets, west of Leningrad, a distance of 700 miles or so from the mines. The coal for this plant comes from Vorkuta at the northern extremity of the Urals, over 1,000 miles away.

Soviet steel production is based partly on widely spaced ore and coal reserves, and Russia is the only major steelmaking nation with large reserves of high-grade ore. It is also the only one with fairly adequate domestic supplies of the ferroalloy metals which are so necessary for the manufacture of high-quality steels.

POLAND AND CZECHOSLOVAKIA. The iron and steel industries of Poland are located mostly in the large Silesian coal field of southern Poland, which extends into Czechoslovakia. Within Poland there are small, low-grade iron-ore deposits nearby at Czestochowa and the Kielce-Radom area. Nowa Huta, the major Polish steel plant, was built in the post-World War II period, some distance east of the coal basin, near the city of Cracow, but the Silesian area has remained an important steel producer.

Czechoslovakia has iron ore, coking coal, and limestone in Bohemia, the western part

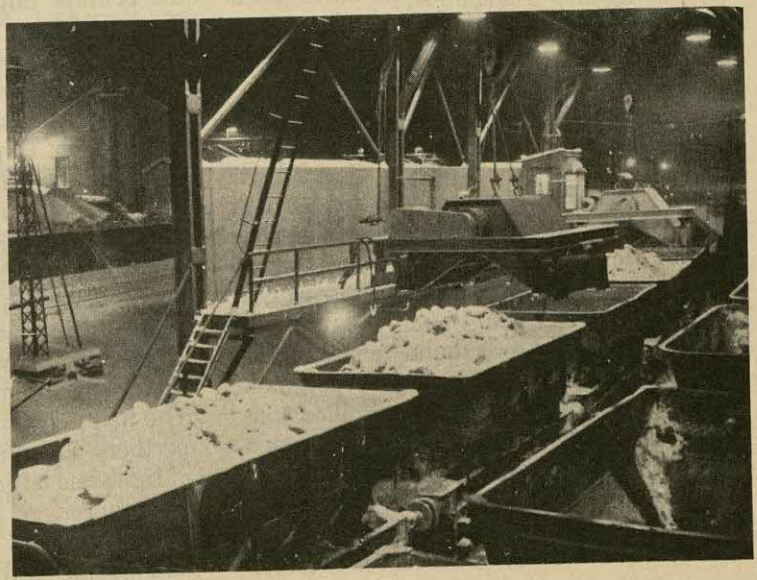


Fig. 302. Winter scene, Narvik, Norway. Swedish iron ore is exported through this port. Ore cars are jolted here, so as to make the frozen ore come loose.

Courtesy Swedish National Travel Office, New York, N.Y.

of the country, and steel production is located in this area, near Prague, as well as in the small portion of the Silesian basin that lies in Czechoslovakia.

Yugoslavia, Hungary, and Romania each produce small quantities of iron ore and modest quantities of steel, all having integrated iron and steel plants.

Africa. Iron-ore mining is also increasing rapidly in Africa under the stimulus of increased demand from the United States and Europe as high-grade reserves in these heavily exploited parts of the world decline. The major producing regions are northern Africa, the western coastal territories, and South Africa. Northern Africa and South Africa have produced ore for some decades, while exploitation on the west coast is recent.

In northern Africa, Tunisia, Morocco, and Algeria together normally produce about six million tons of ore. The location of the mines close to the large ore-consuming centers of Europe is an advantageous one.

The main ore-producing country on the west coast of Africa is Liberia, where production of over four million tons a year was attained in the early 1960's, most of it going to the United States. There is small production in Sierra Leone and in Guinea. Within the past decade large deposits of high-grade, direct-shipping ore have been discovered in a number of West African territories. Since the internal market is as yet small, they are exploited for export purposes, and commonly by European or American companies. The road and rail system of Africa, with the exception of northern Africa and South Africa, is so inadequate that overland transport costs are among the highest in the world. Only deposits close to the coast can be exploited because of cost of transportation.

In South Africa ore found in the Transvaal contains from 50 to 60 per cent iron. Production is about three million tons. South Africa is the most industrialized nation of Africa, and the local steel industry absorbs much of the iron ore produced. The two centers of the industry are Pretoria and Vanderbijl Park. The South African steel industry is relatively new, the first steel having been produced in 1934.

Asia (minus the Soviet Union). The ore resources, insofar as they are known, do not seem to be very large, but they are fairly widely distributed. Ore production is not as large as that in Europe or Anglo-America. However, the heavy industry aspect of the Industrial Revolution is just now taking hold over much of Asia and, given some measure of political stability, iron and steel production may increase quite rapidly.

The largest increases in steel production apparently have taken place in China. Average production was reported to be 2 million tons during the period 1951-55, and by 1960 it was reported to have attained over 20 million tons.

The ore reserves of China have been estimated to be large. Much of the ore, however, may be of comparatively low grade. Production of iron ore in the early 1960's was reported to be as high as over 50 million tons. Major iron deposits are found in southern Manchuria and in the provinces of Hupeh, Shantung, and Fukien, and small deposits are scattered widely throughout the country. The main steel-producing centers are located at Anshan, southern Manchuria; Wuhan, near Hankow; and others near Peking and Chungking.

Iron-ore production in Japan is small, and the country imports ores from well over a dozen different sources, some as far away as Brazil and certain African countries. Also much coal has to be imported. Despite these apparent impediments, during the post-World War II period steel production has increased greatly: in 1950 it was 5 million tons, in the early 1960's about 25 million tons. During this decade Japan became the world's leading shipbuilding nation, depending on locally produced steels. The increase in Japanese steel production can be accounted for on the basis of both rapidly expanding domestic and export markets. The main centers of steel production are in northern Kyushu and in southern Honshu.

India has large bodies of high-grade, low-phosphorus ore, containing 60 to 62 per cent iron. The major mining areas are in Bihar and Orissa, and in the latter state discov-

eries of large reserves of iron ore have been recently made. The older iron and steel industry centers on Jamshedpur, near ore and good coking coal. Newer centers have come into production at Bhilai, with Soviet assistance; at Rourkela, with German aid; and at Durgapur, with British aid.

Among the other iron-producing nations in Asia are Malaya, the Philippines, North Korea, and Turkey. A small steel industry exists in North Korea and Turkey.

Australia. The Iron Knob area of South Australia is the main producing district, with lesser production in Western Australia south of Perth, and at Yampi Sound on the northwest coast. Ore production is of the order of four to five million tons per year. There are integrated steel plants located in the coal field at Newcastle, New South Wales, and near Iron Knob, the ore center. Ships haul coal and ore both ways to these plants.

STEEL MANUFACTURE—INDEX OF INDUSTRIALIZATION

In an industrial economy, iron and especially steel are used for a multiplicity of purposes, one of which is basic to modern methods of production, namely their use for the manufacture of tools and machines. High per capita production in agriculture, mining, manufacturing, or transportation is possible only through use of steel tools and modern power-driven machinery. Thus steel manufacture and consumption in a country furnish a fairly good index to the degree of its industrialization.

The use of machines is increasing all over the world, and if people are to be given higher standards of living, this is a basic necessity. No wonder, then, that the iron and steel industries of the world have been expanding rapidly since World War II. In the three major producing complexes, the United States, the European Economic Community, and the Soviet Union, trends have been upward, particularly in the latter two. But there have been increases practically across the board, even in countries such as Egypt, Turkey, and Colombia. In China and Japan the increases have been almost spectacular. It can be expected that in coming decades many countries will desire to set up their own production facilities, and that total production of steel will continue to increase, as such production is the pacemaker for all other forms of industrial progress.

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25

The Ferroalloy Metals

strategic importance of minor resources

THE OBJECTIVES of this chapter are to aid us further in understanding why the modern steel industry requires supplies of a number of minor metals for alloying purposes; what the most vital ones are; where the sources of supply of these metals are located; what the degree is to which the American steel industry can rely upon domestic resources and the extent to which it now depends upon raw materials that must come from abroad.

For centuries different types of steel could be made only by varying the carbon content within rather narrow limits—from less than 1 per cent to 1.6 per cent—and by varying the rates of heating and cooling during the treatment of the metal. Quality depended largely upon the purity of the ore, and upon the skill of the producers in managing the smelting and other processes in such a manner that the steel would acquire the hardness and toughness necessary for specific uses. Much steel was made into swords, knives, and other cutting tools, and the ability to retain a sharp edge was therefore a very desirable quality. Carbonate ore, or siderite, was used frequently, as it is generally free of sulfur and other deleterious elements. The steel thus made was often of very high quality, but the quantities produced were small, and prices high. In addition, the number of different types of steel that could be made was rather limited.

Steel as we know it today contains not only varying amounts of carbon, but may also contain certain proportions of one or more so-called alloy metals. As a result many more different types of steel can be manufactured today, each designed for a specific purpose. The metallurgy of steel has become a highly complex branch of science, with established principles as guides to procedures. Modern research is forever finding new and useful combinations of iron and alloying metals.

ALLOY STEELS

Almost all steel is still made by following the essential principles and processes outlined in the preceding chapter: reduction of iron ore to metal in the form of pig iron,

purification of a furnace charge of pig iron and scrap iron, and, finally, adjustment of the composition of the metal to what is desired for a specific purpose. The latter point refers to the regulation of the content and structure of the finished product by temperature control and by the addition of such metals in closely measured amounts as are necessary to produce steel of the type desired. The metals added are known as *ferroalloy metals*, of which the most common ones are manganese, molybdenum, nickel, chromium, vanadium, tungsten, and cobalt. Steels that include at least 1.65 per cent manganese or any of the other nonferrous metals are known as *alloy steels*. The additives are rarely used in pure form but in combinations referred to as ferroalloys, such as ferromanganese, ferrochromium, and many others.

During the 1956-60 period, the average annual production of the alloy steels ranged from 6 to 10 million short tons in the United States and constituted 8.5 per cent of the total American output of steel.

Importance of the alloy metals. With recognition of the raw materials vital to the iron and steel industry—ore, coal and coke, and fluxing material (usually limestone)—and the essential procedures indicated by blast furnaces, steel converters, and rolling mills, the grosser materials and processes have been outlined as fully as seems warranted within the scope of this study. We still need to make clear why steels differ in specific quality and how they are truly "tailor-made" to meet certain needs, such as are typified by stainless steel, high-speed and other tool steels, high-temperature steel, and so forth. For that explanation we must turn to the alloy metals, which can be used in varying percentages, singly or in combination, to produce such a variety of results as to bewilder the imagination of the novice; the details lie in the complex field of metallurgy wherein the scientific advances during the past quarter of a century have indeed been astounding. While these details do not come within our province, the broader effects of the important alloy steels are of such industrial and economic significance that economic geography would be amiss if it gave no recognition to the ferroalloy metals which produce them.

MANGANESE

Manganese is essential to the production of good-quality carbon steel. In the manufacture of such ordinary steel, small amounts of manganese are used to remove the oxides formed by the melting of the iron that precedes the steelmaking process and also to remove sulfur compounds. Manganese used as a ferroalloy metal adds many desirable qualities to steel. Steel that contains a very high percentage of this metal is known as *manganese steel*. Although manganese serves a number of other purposes, particularly in the chemical industries, 95 per cent of its production is used in the metallurgical industries.

Manganese is usually added to steel as ferromanganese, an alloy of iron that contains about 80 per cent manganese; 80 to 90 per cent of all manganese used in the manufacture of steel is added in this form. Some *spiegeleisen*, an iron-manganese alloy that in the standard grade contains 20 per cent manganese, is still used. Because of its much greater efficiency in steelmaking, ferromanganese is preferred over spiegeleisen by steel manufacturers, even though its cost per unit is greater. Also, some silico-manganese and some electrolytic manganese are used.

Manganese steel is tough, hard, and resistant to abrasion and corrosion. Steel rails made of manganese steel are reported to be five or six times as durable as those made of ordinary carbon steel. Manganese steel is preferred for heavy-duty machinery, such as that used in mining, rock crushing, milling, road working, and dredging. It is also used in certain types of tool steel, especially where the tools are to be subjected to severe abrasion or to hard impacts. In the electrical industries it is used extensively because, if the content of manganese is as high as 11 to 14 per cent, steel can readily be made nonmagnetic and so becomes a much poorer conductor of heat and electricity than ordinary steel. Thus manganese is indispensable to the modern steel industry. No adequate substitute has as yet been discovered.

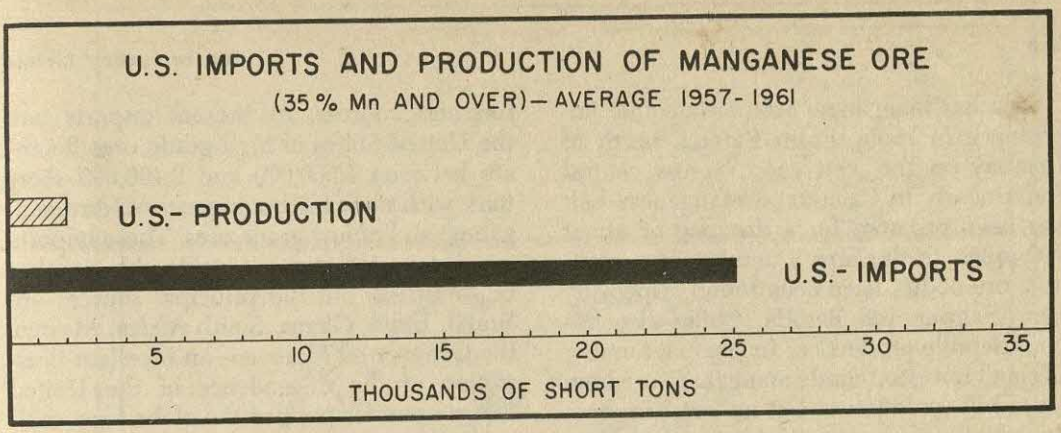


Figure 303.

Manganese is similar to iron in its occurrence, and it is present in many iron ores in considerable amounts. Iron ores containing from 5 to 10 per cent manganese produce a high-manganese pig iron for which there is some demand. Such ores are referred to as *manganiferous iron ore. Ferruginous manganese ore* contains from 10 to 35 per cent manganese, and *metallurgical manganese ore*, 35 per cent and over. For the manufacture of ferromanganese only metallurgical manganese ore can be used, and then preferably with a manganese content of over 45 per cent.

Manganese ores in the United States. Although 2,000 or more occurrences of manganese have been reported in the United States, only a few appear to have any commercial possibilities—at Butte, Montana, in the Phillipsburg area in Montana, in New Mexico, Arizona, and Nevada. At present the latter two states are the major producers of metallurgical manganese ore.

Manganese ores, mostly of low grade, occur in Minnesota, Tennessee, California, Virginia, and Georgia. In connection with the iron ores of the Lake Superior district, manganiferous iron ore in substantial amounts and some ferruginous manganese ore occur in the Cuyuna Range in Minnesota and in the Gogebic Range in Michigan, of which the former is of value for the manufacture of manganiferous pig iron. Minnesota is the only shipper of appreciable quantities of ferruginous manganese ore.

On the whole, therefore, the United States is sadly lacking in known reserves of high-grade manganese ores, so essential to the steel industry, and apparently must continue to be dependent upon foreign sources to supply most of its needs (Fig. 303).

Important foreign sources of manganese. Low-grade manganese ores are quite common in the world, but the really high-grade deposits desirable for the manufacture of ferromanganese are much less numerous.

The Soviet Union contains the greatest known reserves of such deposits and has in the past accounted for the largest production; in recent years the Soviet Union has produced between 40 and 45 per cent of the world supply. South of the Caucasus Mountains and not far from the Black Sea port of Batumi, a bed of manganese ores has been reported to underlie an area of more than 100 square miles. The main ore bed is a sand, 6 to 10 feet in thickness, containing manganese nodules. After washing and concentration, the concentrate carries 50 to 53 per cent manganese. Another important deposit is that of Nikopol in the Ukraine, located close to the Krivoi Rog iron ore region north of the Black Sea. The beds are extensive and are reported to be up to five feet thick. Several other deposits have been proved, and it appears certain that the Soviet Union is endowed with huge reserves of high-grade manganese ore (Fig. 304).

In Europe, west of Russia, numerous small deposits of manganese ore have been found in many of the countries, as they have been found in the United States, but large-scale production has not proved possible even with the financial inducements that have been extended by the several governments.

Asia has manganese ore of economic importance in India. From Baroda, north of Bombay on the west coast, across central India nearly to Calcutta, a manganese belt has been reported for a distance of about 700 miles. In this area a number of exploitable ore bodies have been found, especially near Nagpur and Baroda. China also has considerable production. In Japan a number of small but good-grade manganese ore bodies are in exploitation, but no large reserves have been discovered. Hokkaido and Honshu have contributed the major part of the output in the past, the best-known center being near Kyoto.

In Africa there are two major centers of exploitation of manganese ore, one in Ghana and one in South Africa, northwest of Kimberley. Reserves are reported to be substantial in both areas, and the ore is of high quality. Other African shippers of high-grade ore are the Congo (Katanga copper area) and Morocco.

In the Western Hemisphere, Brazil is the principal exporter, especially from the Amapá area, north of the mouth of the Amazon river, and from the Urucum deposits of western Brazil, located at the Bolivian border near the town of Corumbá. Reserves of high-grade manganese ore have been estimated to exceed 10 million tons in the state of Minas Gerais, where Ouro Prêto is the principal mining center. High-grade manganese ores are also reported to have been found in Mato Grosso to the west. Other production of some importance comes from northwesternmost Guiana and from the Coquimbo area of Chile.

Summary. The Soviet Union is the only major steelmaking country that has sufficient manganese within its borders to meet its own demands. China and India, producers of some note, also can provide for their own needs. The other large steelmaking countries must depend upon imports. These include particularly the United States, the United Kingdom, Germany, Japan, France, and Belgium. During the prewar period the United States imported about 750,000 tons of manganese ore per year, but during the war years imports of ore were nearly doubled, with India and Ghana ranking as the foremost sources. At present imports into the United States of high-grade ores fluctuate between 1,500,000 and 2,400,000 short tons, with some further imports of ferromanganese and of low-grade ores. These imports are distributed over a considerable number of countries, but the principal sources are Brazil, India, Ghana, South Africa, Mexico, the Congo, and Morocco—an excellent illustration of the dependence of the United States upon far parts of the globe for a critical raw material.

CHROMIUM

Metallic chromium is bluish-white in color. It possesses high metallic luster and is very hard. The properties of chromium render it valuable for many uses, particularly as an alloy. The ore from which most chromium is derived is chromite ($FeO{\cdot}Cr_2O_3$), with a theoretical content of 68 per cent of chromic oxide (Cr_2O_3). Chromite is dark in color, from black to yellowish-red, and it is infusible.

The world's production of chromite is used primarily in the metallurgical industries, but considerable quantities are still used for refractory purposes, and smaller quantities in the chemical industries. Chromite is used in the making of refractories such as bricks for lining open-hearth steel furnaces, for which use a resistance to fusion under very high temperatures is of paramount importance. In the metallurgical industries chromium is an essential material for the manufacture of stainless steel (which contains 18 per cent chromium and 8 per cent nickel), for tool steels, and high-temperature and many other alloy steels. In the making of steel, chromium imparts strength, toughness, hardness, resistance to corrosion, and high electrical resistance. Hard steels are used in the automotive industry, in the manufacture of airplanes, high-speed tools, engine parts, and various types of light and heavy equipment. One of the most common uses of metallic chromium is in plating other metals.

Chromite in the United States. In this country the first well-established output

PRINCIPAL PRODUCERS OF MANGANESE ORE
(30 % TO OVER 50 % Mn)
AVERAGE 1957 - 196'
THOUSANDS OF SHORT TONS
6,000
2,000
1,000
500
200
MEXICO
U.S.A
BRAZIL
MOROCCO
GHANA
CONGO
U. OF S. AFRICA
RUMANIA
U.S.S.R.
INDIA
CHINA
JAPAN

Figure 304.

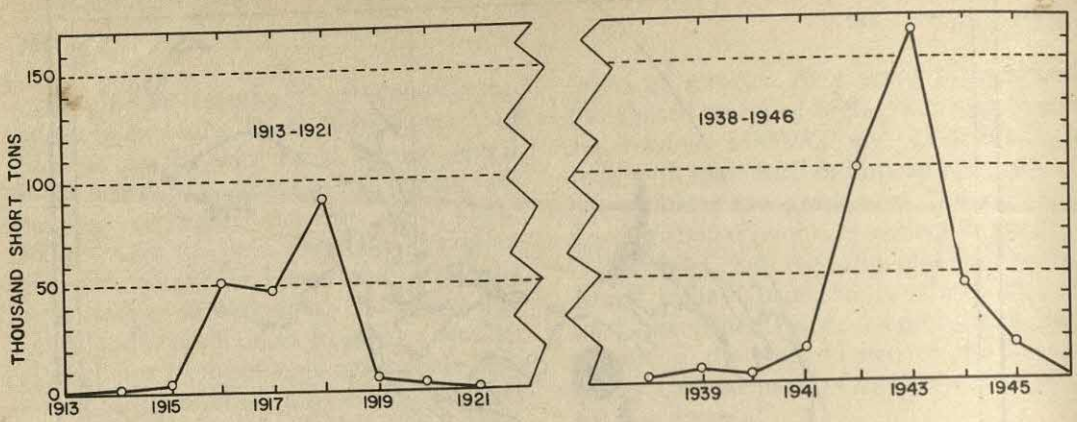


Fig. 305. Chromium production in the United States during the war periods. Domestic production during the interim years was almost negligible.

came from the Reed Mine in Maryland in 1827. Thereafter the United States led the world in chromite production until 1860, after which other producers took the lead. At present United States production is not more than about 2 per cent of world production.

Chromite-bearing rocks are known to occur in the mountainous areas of North Carolina, Maryland, Montana, and Wyoming. The largest deposits occur along the coast of California and in Montana, with smaller deposits reported from Oregon, the Valley of California, and Washington. Since most of the chromite deposits discovered thus far are of low grade and expensive to exploit, domestic production has been small except during war periods, when the need for chromium for war industries became critical, and imports from foreign countries were greatly reduced. The records show that from 1880 to 1946 only 20 per cent of the total chromite production of the United States occurred during peace years, whereas 80 per cent was produced during the two war periods, 1914-18 and 1941-45. During World War II the total output of the United States was 357,000 short tons, of which California and Montana produced 90 per cent, and Oregon, 8 per cent. Small quantities were produced by Alaska, Washington, and Idaho. At present Montana is the only producer, in a small area located a short distance to the northeast of Yellowstone National Park (Fig. 305).

Supplies of chromite elsewhere. The Soviet Union ranks foremost among the nations in output of chromite and in reserves. Large reserves have been proved in the Ural Mountains from the Perm (Molotov) area southward. Some sources have estimated the total known reserves as high as seven million metric tons (Fig. 306).

In Southern Rhodesia (Federation of Rhodesia and Nyasaland) chromite occurs in seams and lenses associated with the Great Dyke, a long, narrow strip of basic rocks which extends for over 300 miles from north to south, a short distance west of Salisbury. The chromite from South Africa is used largely in the chemical industries, while that from the Philippines is best suited for refractory manufactures.

In general, the great industrial nations are the ones that use and must have access to chromium in connection with steelmaking. The demand for chromite is therefore in proportion to the steel output. Aside from the Soviet Union, the great steel-producing countries are dependent upon imports for their supply of chromite. Since chromite is a *must* for steel manufacture, it follows logically that the capital interests of steel-producing nations have invested heavily in chromite-producing corporations abroad, such as British capital in Southern Rhodesia and South Africa, French capital in New Caledonia, and American capital in the Philippines.

The United States imports chromite of metallurgical grade mostly from Southern Rhodesia and Turkey; refractory and chemical grades are imported from the Philippines and South Africa.

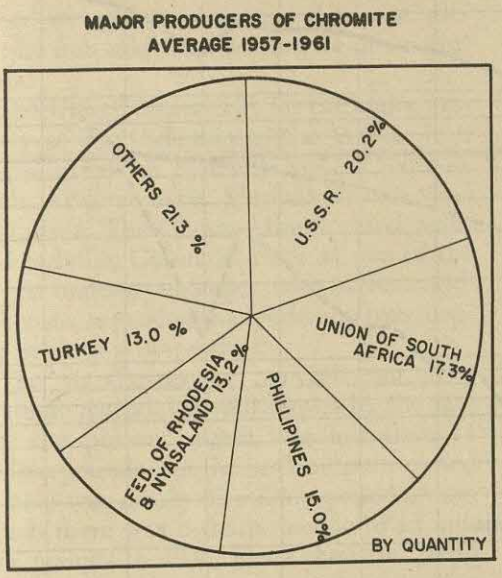


Figure 306.

NICKEL

In the United States approximately 40 per cent of all nickel is used in the making of stainless steel and other nickel steels, the remainder being used mostly as alloying material with copper, aluminium, and other metals and for electroplating. It is important in the superalloy field for high-temperature service, as in jet engines. Nickel alloys are used for steel subject to corrosion, great temperature changes, heavy loads, and abrasion. Low-nickel steels (0.5 to 0.7 per cent Ni) are tough, strong, and ductile. High-nickel steels (7 to 35 per cent Ni) are heat- and corrosion-resistant. Nickel steels are adapted to a wide variety of uses, from cooking utensils and precision instruments to armor plate. Nickel plating is used to prevent corrosion and thus is extensively employed in the manufacture of food containers because of its resistance to attack by weak acids.

Occurrence of nickel. The United States has a small production of primary nickel from a deposit in Oregon, and some nickel is a by-product of copper refining. Also, modest quantities of nickel are recovered from scrap. By far the bulk of the nickel consumed, however, must be imported. Fortunately, the world's largest nickel-bearing area is located nearby, in the Sudbury district of Ontario, about 250 miles east of Sault Ste. Marie. The ore area is about 36 miles long and 16 miles wide; it has about 20 active mines and is reported to contain reserves sufficient to meet the world's needs for decades to come. Because of the great output in the Sudbury district, Canadian exports dominate the world's trade in nickel (Fig. 307).

Outside of Canada the known deposits of nickel ore are widely scattered, but small. In the nineteenth century New Caledonia was the leading producer of nickel, but since then Canada has held undisputed leadership. Reserves in New Caledonia are said to be still ample and easily mined, but the ore is low in metal content.

Ores similar to those at Sudbury occur scattered in small bodies in northern Finland and near Pechenga (formerly Petsamo) in Russia. Development of the latter deposit, then in Finland, was largely by American capital during the prewar period, and ores containing 3 per cent nickel were being produced. Production was interrupted by World War II, and in 1944 the Petsamo area was ceded by Finland to the Soviet Union. Nickel has also been found in the Kola Peninsula and in the Ural Mountains of the Soviet Union, but little is known concerning reserves.

The United States normally consumes between 30 and 40 per cent of the world's supply. The world demand has generally been met by exports from Canada, to the extent of 85 per cent of the total, and from New Caledonia, to the extent of about 10 per cent. Minor quantities have been provided from other sources.

Summary. Nickel is one of the most important metals as an alloy for ferrous and nonferrous metallic products and is considered to be vital as a strategic metal for ordnance purposes. Inasmuch as the Soviet Union has been inadequately explored, it is likely that within its vast territory nickel sufficient for its own needs may be uncovered. During the foreseeable future, Western Europe, including the United Kingdom, must depend largely upon imports, as does the United States.

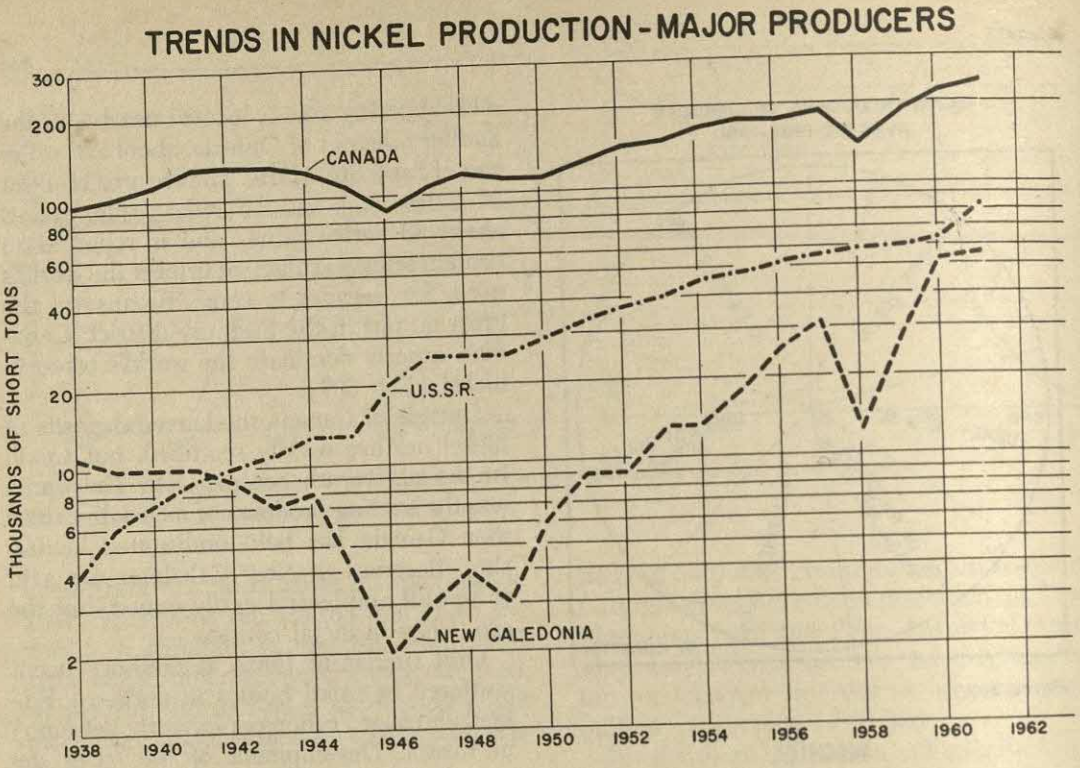


Figure 307.

MOLYBDENUM

In the years immediately preceding World War II molybdenum was used as an alloying metal in about 30 per cent of the total tonnage of alloyed engineering steels. During the war period the value of molybdenum became increasingly appreciated, with the result that in 1949 molybdenum was reported to be a component of about 80 per cent of the alloyed engineering steels being made. This increase was due partly to greater availability but mostly to the wider application caused by new uses.

Molybdenite (MoS_2) is the principal ore. Production data are usually given in terms of concentrates which range from 48 to 49 per cent metallic molybdenum and are expressed in tons of ore. However, it is preferable to use data given in terms of metallic molybdenum contained in the ore or concentrate, in which case quantities are stated in pounds rather than in tons. In general, both domestic and foreign data can be, and in most cases have been, converted to terms of metallic molybdenum contained in the ore or concentrate.

It is claimed that molybdenum is the most effective element in contributing high-temperature strength to ferrous alloys, and that it produces a finer grain-structure. It is used extensively in high-temperature alloys developed for components of gas turbines, jet engines, and turbosuperchargers.

In general, molybdenum is used in a wide variety of alloy steels, particularly in ordnance and high-tensile steels. It imparts high resistance, as does tungsten, against "creep" of metal at high temperatures, or elongation under stress. It contributes depth-hardness, thereby making possible tools which are adapted to high working temperatures and yet which will retain their hardness without becoming brittle upon cooling. Molybdenum may replace part or all of the tungsten used for this purpose. Molybdenum is now added to stainless steel to improve resistance to some types of severe corrosion. Furthermore, it has been found that molybdenum in connection with chrome and nickel, one or both, makes a superior alloy for use in the manufacture of certain automotive parts, as well as in that of armor plate. In the United States about two thirds of the molybdenum pro-

duced is used in steels, and the remainder in cast iron and for a number of other purposes.

The United States is by far the major producer of molybdenum in the world. It is produced by six states, namely, Colorado, Utah, Arizona, New Mexico, Nevada, and California. The Climax Mine located north of Leadville, Colorado, rates as one of the largest underground operations in the world. Other states produce molybdenum from copper ores, as a by-product.

The significance of molybdenum as a strategic material is well shown by the fact that the prewar output was less than 11 million pounds, but the peak output reached in 1942 was nearly 62 million pounds, from which there was a sharp decline to 18 million pounds in 1946. Since then the trend has been generally upward, and production reached a figure of around 70 million pounds in the early 1960's.

Molybdenum, to nearly the same degree as chromium, has become recognized as an alloy metal essential for the iron and steel industries. In this metal the United States holds such a predominant position that it is in virtually monopolistic control. The only other countries with any appreciable production are the Soviet Union, Chile, China, Japan, Canada, and Norway. Unless further exploration should reveal sources unknown at this time, the leadership of the United States in output of molybdenum ore appears certain to continue for the foreseeable future.

TUNGSTEN

Tungsten has become almost indispensable in modern metallurgy, and particularly so in the manufacture of alloy steels. Its importance is due to the toughness, strength, hardness, and resistance to abrasion which it engenders in tool steels, endowing metal-cutting tools with the ability to retain their strength and efficiency at temperatures and speeds that destroy ordinary steel tools. This ability to stand up at high speeds is particularly important in our era of rapid mass production. Tungsten carbide facings on cutting tools of ordinary stock are widely used. If the whole tool is made of tungsten carbide, a substance second only to diamond in hardness, it will last from 25 to 50 times as long between sharpenings as will the best ordinary high-speed steel.

High-tungsten steels, which contain 15 to 20 per cent tungsten and 4 to 5 per cent chromium or molybdenum, retain structure and cutting edge even at red heat. This quality makes possible the operation of metal-cutting machinery at otherwise impossible speeds and imparts the name "high-speed steel." Tungsten is highly desirable for valves and valve sets in internal-combustion engines, where high temperatures are continually met. It is also used in cold chisels, hack saws, files, razor blades, springs, armor plate, and armor-piercing shells.

The most generally known use of tungsten, and one of its important uses, is as a filament in electric light bulbs, although the quantity consumed for this purpose is comparatively small. Tungsten has high electric resistance and a very high melting point, thus allowing a surprising degree of efficiency in the conversion of electricity into light. No satisfactory substitute for tungsten as an electric-light filament has yet been found.

Sources of tungsten ore.[1] During the decade closing with 1960, the world output of tungsten concentrate virtually doubled from about 30,000 to about 70,000 short tons. China has long held leadership in production, followed by the Soviet Union and the United States, with lesser amounts provided by a number of countries widely dispersed over several continents (Fig. 308).

The total output of tungsten ore in the United States reached a peak during World War II in 1943, and this was followed by a decline of more than 50 per cent in 1946. In recent years American production has fluctuated between 4,000 and 15,000 short tons, requiring considerable imports, mostly from Brazil, Bolivia, Portugal, South Korea, and Australia.

Brazil is a newcomer in the field of tungsten production. Production began about 1940 and increased spectacularly to meet

1 Wolframite is known as the source of tungsten, and statistics are generally given in terms of concentrate, 60 per cent WO_3.

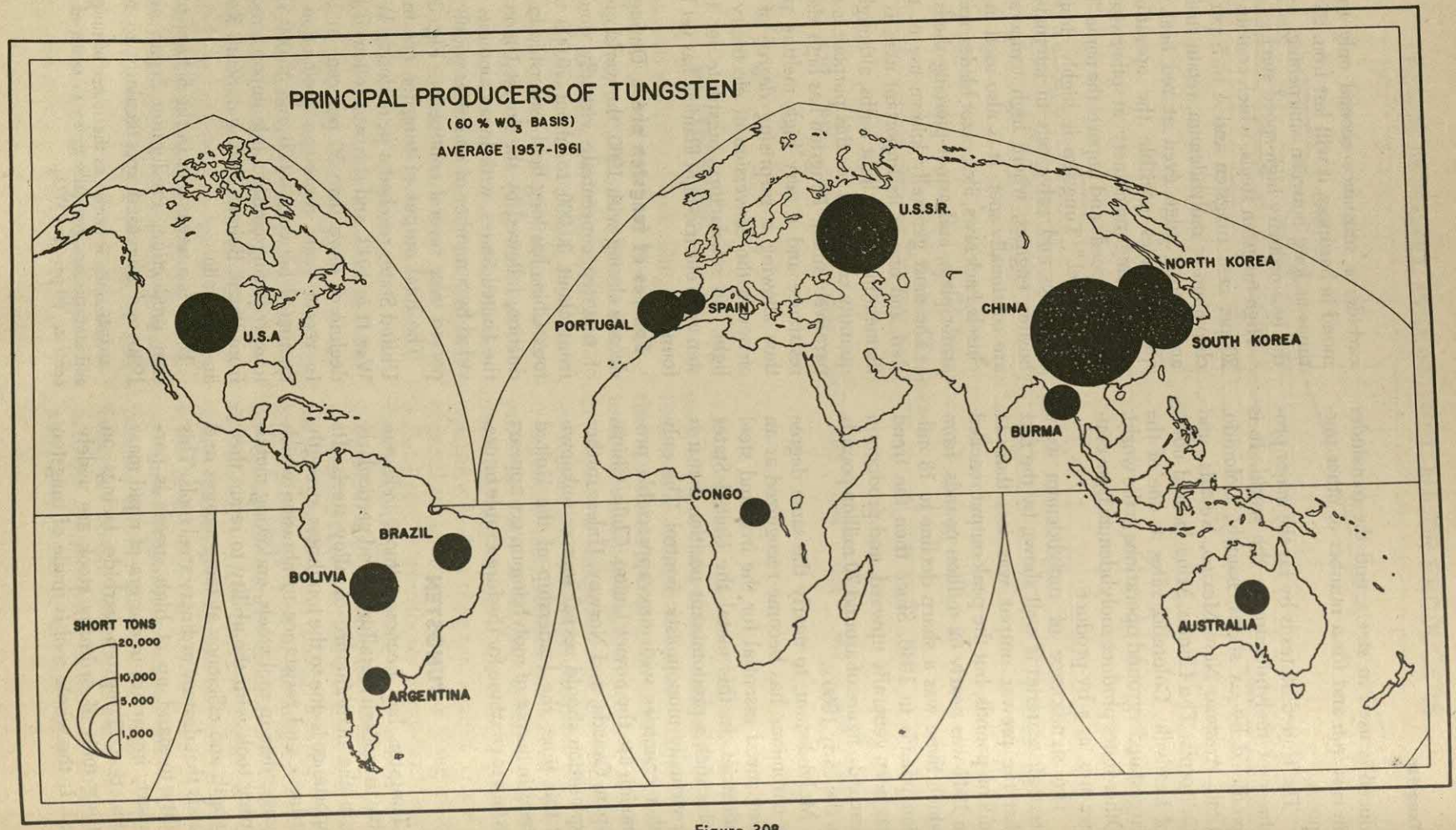

PRINCIPAL PRODUCERS OF TUNGSTEN
(60 % WO3 BASIS)
AVERAGE 1957-1961
U.S.S.R.
NORTH KOREA
CHINA
SOUTH KOREA
PORTUGAL
SPAIN
U.S.A
BURMA
CONGO
BRAZIL
BOLIVIA
AUSTRALIA
ARGENTINA
SHORT TONS
20,000
10,000
5,000
1,000

Figure 308.

the demands of the war period. Since then it has declined, but Brazil still retains an important position as a source of tungsten to meet export demands, particularly to the United States. Bolivia has long been a consistent producer and still remains so, most of the production being from the deposits in the province of La Paz. Minor producers are Argentina and Peru. As a whole, Latin America promises to continue to be an important source of tungsten for the United States.

In Europe, Portugal has long held an important position in its output of tungsten ore. The country was strategically situated to supply ore to the central powers of Europe and the Western Allies during World War II, and as a result prices soared, and the output of tungsten in Portugal was increased twentyfold by the time the peak was reached in 1943. After that there was a virtual collapse, but production has been resumed on a more modest scale.

In Asia, China, long in the lead, and the Korean peninsula, have been the principal sources. There seems no doubt that the reserves in China are large.

Australia has produced tungsten ore in moderate quantities for many years, but unlike in some of the other centers of production, there has been no decline during the postwar period.

Summary. The significance of tungsten as an essential material for war supplies and for ordnance is emphatically illustrated by the decline in the total world output, which dropped from 61,000 tons in 1943 to 19,000 tons in 1946. World production, however, has increased again, and in recent years has fluctuated between 56,000 and 83,000 short tons. For the foreseeable future, the major centers of production of this alloy material, vital in so many phases of the iron and steel industries, will continue to be China, the Soviet Union, the Korean peninsula, and the United States.

VANADIUM

Vanadium is one of the most recent alloy metals to become available in industrial quantities. Although the element is widely distributed, the available ores are generally of a low grade, and the metal is hard to extract because of metallurgical difficulties. As a result, vanadium is relatively high priced. Nevertheless, it is so useful that demand for it has increased substantially in late years.

The principal use of vanadium is in making alloy steels and iron. It is used in steel manufacture both as an alloying material and as a scavenger. It removes oxides and other impurities, and at the same time it increases the strength and induces finer texture of the steel through grain refinement. Vanadium steels are used extensively in making high-speed and other tool and alloy steels. Vanadium was classified as a "critical" metal by the Army and Navy Munitions Board during World War II, which implies that it is nearly as essential as the metals classified as "strategic." In the early 1960's about 15 per cent of the vanadium was used in the manufacture of high-speed steel, 55 per cent in other alloy steels, and about 13 per cent in non-ferrous alloys. The remainder was used for chemical purposes and for other lines of metallurgical products.

The United States holds a commanding position in the production of vanadium in the world, having assumed that position in 1941. As was true for most of the other alloying metals, the demands of war created a temporary but urgent call for vanadium, which induced rapid expansion of American production. Measured in terms of vanadium content of the ores and concentrates, only a little more than one million pounds were produced in 1937, contrasted with five and a half million in 1943. The postwar decline was nearly as precipitous as the rise, to 1.3 million pounds in 1946. There has been a postwar recovery to a considerable degree, and in recent years production in the United States has fluctuated between 3 and 5 million pounds. The center of vanadium-ore mining in the United States is in the Colorado Plateau region of western Colorado and adjoining areas in Utah, New Mexico, and Arizona, where it is now produced chiefly as a by-product of uranium. World production of vanadium ores is limited almost entirely to three countries—the United

States, South-West Africa, and South Africa (Transvaal).

Inasmuch as the demands of the times call for increasing speed of machines, automobiles, and planes, it seems certain that the ferroalloy metals essential in the manufacture of high-speed steels will all face gradually increasing demand and, to meet it, increasing output. The curve of production of vanadium will probably correspond roughly to the curve of production of high-quality steel. In the light of present knowledge, the position of the United States as a leading producer of vanadium appears to be safe.

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26

The Principal Nonferrous Metals

THE IMPORTANCE of the nonferrous metals to the modern industrial world cannot be overemphasized. Even historically, nonferrous metals took precedence over the ferrous, as evidenced by the term "Bronze Age" and by the early use of gold and silver for tokens of value. Iron came upon the industrial scene late compared with copper and tin. Although it now leads the procession of metals in quantity used yearly to such an extent that we may say that we are living in the "Steel Age," we must bear in mind that industry today is so complex that it makes use of nearly all known metals and uses them in a multitude of combinations, in which both kinds and amounts vary. This mode of use of metals makes possible the great diversity of products that is basic to our high standard of living.

The nonferrous metals that are usually considered to be of major importance in themselves rather than as alloys are copper, aluminum, lead, zinc, and tin. Magnesium, although it is of considerable importance in its own right, has a value to industry based largely upon its use as an alloy with aluminum.

Of the above-named metals, the potential sources of aluminum and magnesium are so large that scarcity need not be anticipated during the foreseeable future. Such is not the case, however, with the other four. The demands for copper, lead, zinc, and tin are so great, and the known reserves of ore are so limited, that shortages of supply are becoming evident in some areas. It is imperative that conservation be practiced by saving scrap metal for reuse as a secondary source of raw material for various manufacturing purposes. For example, during the period 1956-60 the United States produced a yearly average of slightly over one million short tons of primary copper from domestic ores, whereas it produced 875,000 tons from scrap. This has become usual, and we may expect the proportion of copper from scrap to increase during the years ahead.

COPPER

The early use of copper was probably due to the fact that it was found as native cop-

per in a few places and so could be used directly without conversion. Furthermore, copper could easily be hammered and fashioned into desired forms. Its uses were limited by its softness, but it was early discovered that by fusing it with tin, an alloy much harder than either metal could be obtained. This substance, *bronze,* was far superior to stone for fashioning tools and weapons, and thus man progressed from the New Stone Age (Neolithic) into the Bronze Age. Later bronze came into use for making coins because of its durability and the readiness with which symbols could be stamped upon it. Although from very early times copper ranked among the most desired metals, the demand grew only slowly until the development of the electrical industries gave rise to an unprecedented need for copper in connection with generating and transmission facilities. Copper met this need because of several essential properties, but especially because of its conductivity of electrical energy, its ductility, and its malleability. Ductility makes possible the fine copper wire now essential in electrical equipment, while malleability permits hammering the metal into plates and sheets.

Copper ores. Copper minerals varying from *native copper* to complex chemical combinations are found in rock formations of nearly all geologic ages. Generally the copper minerals are more complex than the iron minerals, and since they occur mostly as crack fillings in rocks, so-called veins, or finely disseminated in rock masses, the ore as mined consists of a small percentage of copper minerals and a high percentage of rock material known as gangue. Some of the largest and most important mines yield ores which contain less than 1 to 3 per cent recoverable copper, while ores which yield 6 per cent or more are deemed to be exceptionally rich. In the United States the average copper content of the ore is only about 0.7 per cent. Fortunately, four fifths of the ore can be mined in open pits on a large scale (Fig. 309).

Location of copper smelters and copper refineries versus that of mines. Because of the low metallic content, copper ores are much too bulky in relation to value to be able to bear the expense of long haulage, and *copper smelters* must therefore be located near the mines. Before it can be smelted, the ore must be *concentrated,* i.e., the metal content has to be increased by mechanical methods that eliminate some of the gangue. At the smelter the ore is reduced to "blister," which contains 98 per cent or more of metallic copper.

For many purposes, however, and especially for use in the electrical industries, the metal must be almost 100 per cent pure.



Fig. 309. Open pit copper mine in Arizona. Compare size of buildings in left middle ground with scale of operations. This is the Morenci pit of the Phelps Dodge Corporation.

Courtesy Bureau of Mines, U.S. Department of the Interior

Purification is accomplished in *refineries*, where largely by electrolytic methods the impurities are reduced to only a few hundredths of 1 per cent of foreign matter. For these operations expensive equipment and cheap electric power are required, and the plants that have proved to be economically practical must be large enough to handle the copper blister from several smelters.

In the United States six large electrolytic refineries are located on the Atlantic seaboard close to the centers of consumption. In addition to concentrates from American smelters, these refineries receive copper in various forms from foreign sources, particularly from Chile, Mexico, Peru, Africa, and Canada. Other refineries, chiefly to serve domestic needs, are located at Tacoma, Washington; El Paso, Texas; Great Falls, Montana; Garfield, Washington; and three small nonelectrolytic plants on the Great Lakes.

Since copper is a valuable metal, recovery from scrap metal—either scrap copper or alloys—is important. In some years in the United States production of so-called secondary copper exceeds that of the domestic mines. When demand for copper slackens, the secondary copper capacity is apt to affect mine production unfavorably.

Mine production, smelter production, and production of refined copper may differ considerably for individual countries. As a result of imports of concentrates, the total production of smelter copper in the United States is generally somewhat larger than that of copper derived from domestic mines. Due to imports of blister and related kinds of copper the production of refined copper usually is considerably larger than that of smelter copper. West Germany has very little mine production of copper, but has important smelting capacity. Japan's smelter production also usually exceeds her mine production, though not to the extent that it does in Germany. On the other hand, some countries, such as Cyprus, the Philippines, and South-West Africa, have mine production but no smelter production. All this signifies that there are fairly important movements of copper concentrates and blister copper, although not to the extent as formerly, when fewer countries had modern smelters and refineries.

Anglo-America is still the major center of copper production in the world.

The distribution of copper mining in the United States and Canada. Roughly, 90 per cent of all the copper mined in the United States comes from Arizona, Utah, Montana, Nevada, and New Mexico (Fig. 310). Other states with significant production are Michigan and Tennessee. In a number of places copper is a valuable by-product of ores mined chiefly for their content of other metals. Twenty-five mines produce most of the United States copper.

The heavy drain upon domestic copper resources caused by war conditions is clearly shown in Fig. 311. During the war years 1940-44, the average annual smelter production of the United States from domestic ores was about one million tons, a level reached again in 1956, 1957, and 1960. Because of increasing population, as well as increasing industrial use of copper, it is reasonable to expect that in the long run the demand for copper in the United States will continue to rise.

Arizona is the major copper-producing state, with a yearly output of between 400,000 and 500,000 tons of recoverable copper. The greatest producing districts of the state are in the southeast portion, from the Mexican border northward beyond Tucson (Fig. 310). In this area the Morenci, Globe-Miami, Bisbee, and Ajo districts have become familiar names in the copper world because of the magnitude and availability of their reserves. The ore bodies vary from large low-grade deposits to those of higher grade but of much more restricted extent. While the districts named are the largest and generally the best known, there are also a number of smaller districts being actively exploited, the total output giving Arizona unquestioned supremacy among the copper-producing states. This rank seems assured for many years to come because of the large reserves known to exist in that state.

The Bingham Canyon district of Utah, south of Salt Lake City, is the major single producing district of the United States. The copper content of the ores is only 0.7 per

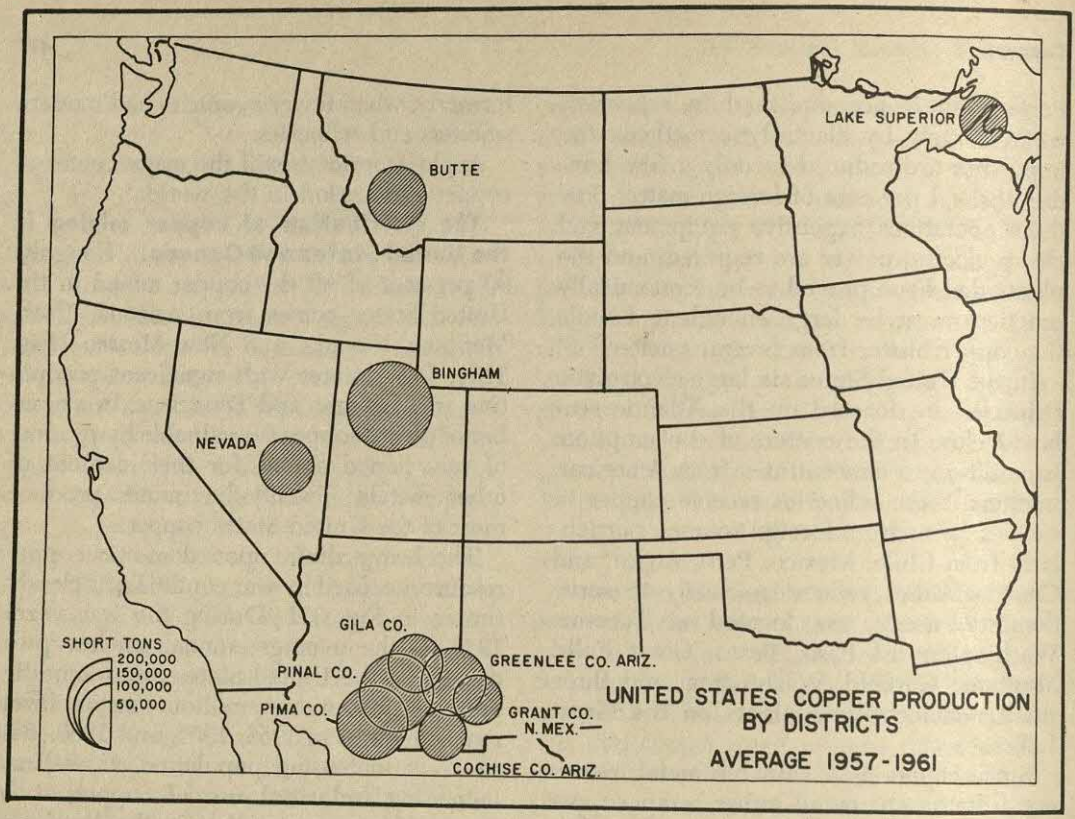


Figure 310.

cent, but operations can be conducted on a large scale. Maximum production occurred in 1943, i.e., during World War II, but is now well below that.

Montana has generally ranked third since 1925 in annual copper production. The chief center of mining operations is the famous Butte district in the heart of the northern Rockies. In this area maximum annual production was attained in 1916, during World War I, but is now only about half of that.

Nevada, New Mexico, and Michigan are producers of more or less equal importance. The first two states, however, have reached appreciable production comparatively recently, while Michigan is an old producing region where present production is less than half of the 1916 maximum. Before white man came, the Indians made some use of the native copper which they found in small quantities in the glacial drift and stream gravels of the Upper Peninsula of Michigan, and, to the French explorers who came to this region, they told stories of hills of copper near Lake Superior. Later the uplands became one of the major copper-producing districts of the world. The ore consists of rock impregnated with metallic, or native, copper. For many years Michigan ranked first in copper output in the United States, but lost this position as a result of the large developments in the western states. Because of increasing depths to which mining operations must extend and the gradual depletion of available ore, the trend of output in Michigan will probably continue well below the maximum which was attained in 1916.

Copper resources in the United States are, insofar as they are known, still large. In the early 1960's the country ranked second in the world, after Chile but ahead of the Federation of Rhodesia and Nyasaland, the Congo, the Soviet Union, Peru, and Canada.

CANADA. Canada is characterized by widespread deposits of copper ores, from Newfoundland and Nova Scotia to British Columbia and the Northwest Territories.

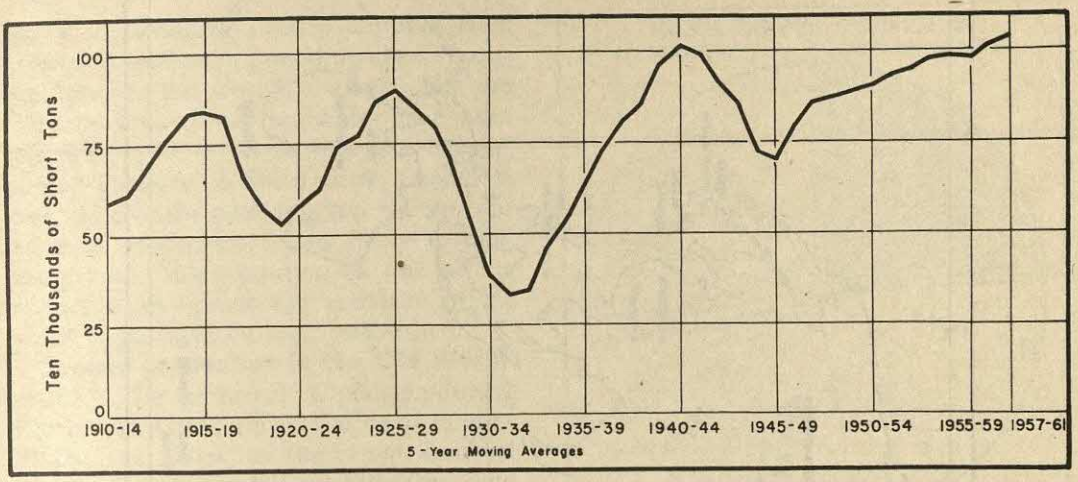


Fig. 311. Copper. Average annual production in the United States from domestic ores by five-year periods since 1910. Suggest reasons for the arches and troughs shown on the graph.

Production, based on metal content of ores mined, was generally below 60,000 short tons until after 1926, when a rapid increase in output began. By 1930 production had more than doubled. In recent years it has been between 300,000 and 400,000 short tons.

The nickel-copper mines of the Sudbury basin of Ontario usually produce about 50 per cent of the Canadian output (see Fig. 312). Northwestern Quebec ranks second in output, and the mines of the Flin Flon area on the border of Manitoba and Saskatchewan, north of the Saskatchewan river, constitute the third important center of copper-mining activity in Canada. British Columbia, although of lesser importance to date than the more eastern centers, is a vast area wherein possibilities for further discoveries and development exist. On the whole, it seems likely that Canada's copper output will increase. As world demand rises, and it now seems almost certain that it will, the search for new ore bodies will be intensified. In that search Canada will undoubtedly play an important part.

Copper production in Latin America. MEXICO. During recent years, Mexico has quite regularly produced from 60,000 to more than 70,000 short tons of recoverable copper per year. The principal producing area includes the mining districts of northwestern Mexico, where general structural conditions and mode of occurrence of copper are similar to those prevailing in southern Arizona. The mines are owned and operated, for the most part, by American capital. The prospects are for maintenance of moderate production, perhaps 1 to 1.5 per cent of the world output during the next decade.

PERU AND CHILE. In Peru the Cerro de Pasco mines north of Lima have long been noted for their copper output. Production is in the neighborhood of 50,000 short tons. A new mine and smelter have recently been opened up in southern Peru, south of Arequipa, which may result in an increase in the country's production. Since 1910, Peruvian production has been below that of Mexico and far below that of Chile.

Chile's position as one of the major copper-producing countries of the world dates back to the early part of the present century. Since 1920 she has ranked second among the nations (Fig. 313). Total annual production of Chile in recent years has been well over 500,000 short tons and on occasions even over 600,000. The principal centers of production are Chuquicamata, El Teniente and El Salvador-Potrerillos (Fig. 312). The ore bodies occur along the west flanks of the Andes. Ocean haulage is within easy reach, an important

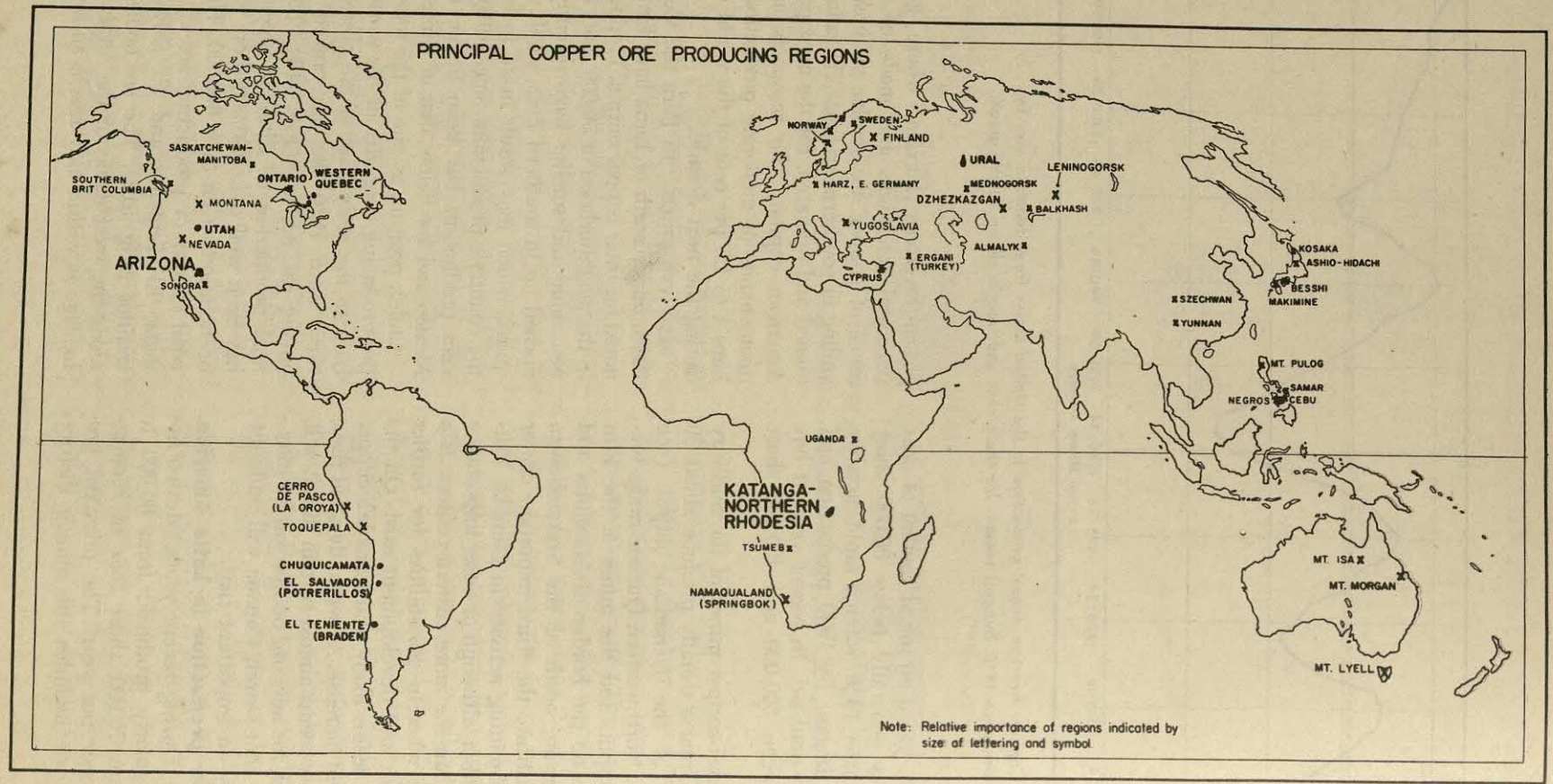

PRINCIPAL COPPER ORE PRODUCING REGIONS
SASKATCHEWAN-MANITOBA
SOUTHERN BRIT COLUMBIA
ONTARIO
WESTERN QUEBEC
MONTANA
UTAH
NEVADA
ARIZONA
SONORA
CERRO DE PASCO (LA OROYA)
TOQUEPALA
CHUQUICAMATA
EL SALVADOR (POTRERILLOS)
EL TENIENTE (BRADEN)
NORWAY
SWEDEN
FINLAND
HARZ, E. GERMANY
URAL
LENINOGORSK
MEDNOGORSK
DZHEZKAZGAN
BALKHASH
YUGOSLAVIA
ALMALYK
ERGANI (TURKEY)
CYPRUS
KOSAKA
ASHIO-HIDACHI
BESSHI
MAKIMINE
SZECHWAN
YUNNAN
MT. PULOG
SAMAR
NEGROS
CEBU
UGANDA
KATANGA-NORTHERN RHODESIA
TSUMEB
NAMAQUALAND (SPRINGBOK)
MT. ISA
MT. MORGAN
MT. LYELL
Note: Relative importance of regions indicated by size of lettering and symbol

Figure 312.

factor in obtaining needed supplies from abroad as well as in providing cheap transportation to the world's markets. The ore reserves, proved and probable, have been reported to be so large that the copper-mining industry of Chile seems assured of long life. For the reasons given, the upward trend of production seems likely to continue, and Chile's position as one of the leading copper-producing countries of the world appears to be well established.

Copper production in the Old World. AFRICA. The principal copper-producing districts of Africa are in the deep interior of southern Africa, on the Congo-Zambezi plateaus, where rainfall is abundant, quite in contrast to the seaboard location and the desert conditions which characterize the Chilean ore fields. The distance of the African copper mines from low-cost ocean haulage is compensated in large measure by the greater richness of the ores. The ore bodies occur in a belt that extends from Northern Rhodesia (part of the Federation of Rhodesia and Nyasaland) into Katanga, the southern part of the Congo. The annual production of Northern Rhodesia in recent years has been from 400,000 to over 500,000 short tons, while that of Katanga has been from well over 200,000 to over 300,000 short tons. (See Fig. 313.) The ores thus far worked in Katanga and Rhodesia average from 2 to 5 per cent copper, which is considerably above the average content of the ore now mined in the United States (0.7 per cent).

Formerly the Katanga and Rhodesian output was handicapped by great distances and the high cost of overland transportation. These were in large measure overcome by the opening in 1931 of the Benguela railroad, which provided an outlet to the west at much lower cost than was possible toward the south or east. The overland mileage was reduced by about 250 miles, and the ocean distance by about 2,600 miles, thus bringing the African mines nearly 3,000 miles closer to European markets. These improved transportation facilities have placed the African mines in position to compete in the world markets with the great copper-mining districts of North

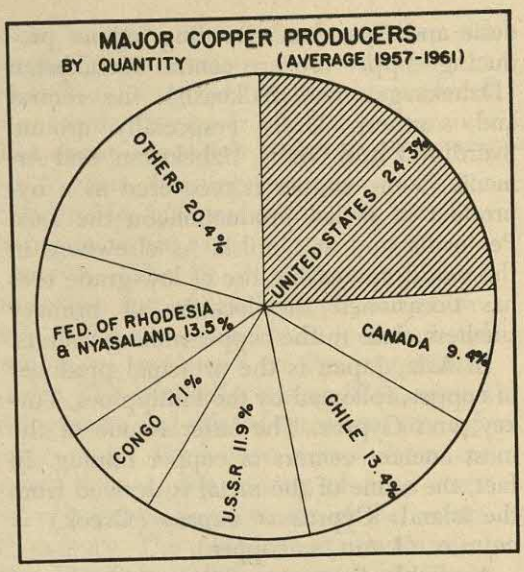


Figure 313.

and South America. Furthermore, the Katanga and Rhodesian ore bodies occur under favorable mining conditions: the ores are rich, labor is comparatively cheap, and water supplies are ample for all needs.

Other producers of some importance in Africa are South Africa, South-West Africa, Uganda, and Southern Rhodesia.

The capital interests involved in Africa are predominantly British, Belgian, and American. The ore reserves of Katanga and Rhodesia are so great that these districts (with production that nearly equals, and in some years exceeds, that of Chile) are now among the foremost producing areas of the world.

Other important copper-producing centers. In Europe copper mining has been carried on for over 2,000 years in southern Spain, and some copper is still produced in the Río Tinto area northeast of the port of Huelva. More important producers are Yugoslavia, Finland, East Germany (Harz area), and Sweden. Total production of Europe without the Soviet Union is, however, less than one third of Chilean production.

In production of copper Russia stands at present in fourth place, after the United States, Chile, and the Federation of Rho-

desia and Nyasaland. Leading regions producing copper ore are central Kazakhstan (Dzhekazgan and Balkhash), the central and southern Urals (especially around Sverdlovsk and Orsk), Uzbekistan, and Armenia. Some copper is recovered as a by-product of nickel production on the Kola Peninsula and at Norilsk. As elsewhere in the world, increasing use of low-grade ores has occasioned the location of primary smelters close to the copper-mining centers.

In Asia, Japan is the principal producer of copper, followed by the Philippines, Turkey, and Cyprus. The latter is one of the most ancient centers of copper mining. In fact, the name of the metal is derived from the island: Cyprus = *cuprus* (Greek) = *cuprum* (Latin) = copper.

Available figures on copper reserves of countries and of the world give only a very partial picture, as they are based upon estimates of probable quantities of copper available in present mining areas, in nearby areas, and in other well-explored regions. In all these areas more copper ore may be found. Furthermore, there are areas of considerable extent in this world where thus far the amount of exploratory work has been limited. These remarks on copper reserves apply equally to the reserve figures for many of the other minerals of economic value.

TIN

The Bronze Age, which followed the Neolithic period and preceded the Iron Age, could not have developed if man had not discovered tin and the fact that it hardens copper. Probably as early as about three millennia B.C. peoples of the eastern Mediterranean region had learned to make bronze, an alloy consisting of about 90 parts copper and 10 parts tin. Since bronze weapons and implements were far superior to stone ones, tin very early became what we would now call a "strategic metal." It was needed for strong armies, and those who traded in it, for example, the Phoenicians, reaped rich profits.

Present uses of tin. At present not more than about 6 per cent of the world's tin production goes into the manufacture of various kinds of bronze. Some modern uses, such as its use in babitt and solders, are based upon the softness and low melting point of tin. The major use of the metal is based on its resistance to oxidation and to corrosion by inorganic and organic acids. Thin steel plate is coated with it and becomes tinplate, needed for the manufacture of food containers. Formerly the steel plate was "hot dipped," but now most plating is done by the electrolytic method. This requires only two fifths as much tin. However, the thickness of the layer of tin is so reduced that its efficacy is not as great, and for some purposes lacquering of the inner surface of tin cans is necessary. The electrolytic method is most popular in countries such as the United States, where turnover of canned products is fairly rapid.

Mode of occurrence of tin. The principal mineral that contains tin is cassiterite (SnO_2), or tinstone. Originally, this occurs in veins that traverse granite or metamorphic rocks, such as schists, occurring in close proximity of granite. Only rarely, however, are the veins sufficiently numerous that it is worthwhile to extract the cassiterite directly from the rock. This is the case, for example, in Bolivia, East Germany, and Czechoslovakia. Much tin has been found in alluvial deposits, in terraces or floodplains—the result of long continued weathering of cassiterite-bearing rocks and subsequent erosion and deposition. These are placer deposits, the source of probably four fifths of the world's tin production. The placers are worked by various means; in low, swampy floodplain areas it is often done by huge dredges that are able to dig down as far as 150 feet. In all cases the "ore" must be concentrated before it can be delivered to smelters, usually to from 60 to 75 per cent tin. Smelters are often located thousands of miles away, a situation which is possible because of the high degree of concentration that can be attained. Thus there is quite an extensive trade in tin concentrates.

Tin and the United States. From 40 to 50 per cent of all the tin for tinplating is consumed in the United States. Besides, the country uses considerable quantities of primary tin for various industrial purposes. As its own production is practically nil, the United States has to depend entirely upon foreign sources for its supply. Unfortunately, the major sources of tin are located far away, mostly in the tropics.

Tin is a comparatively rare metal, a fact often overlooked because of the cheapness of tinplate and the resulting extensive use of tin cans. The annual world output of tin varies from 150,000 to 200,000 short tons, a small quantity compared with that of copper, which runs between 3 million and 4 million. Thus secondary tin, reclaimed from scrap, is an important item in the United States, usually amounting to between 35 and 40 per cent of the annual tin consumption.

The world's sources of tin. The principal tin deposits of the world are a series of placer deposits that lie in a comparatively narrow belt extending from southernmost Burma through the "panhandle" of Thailand to Malaya and the Indonesian islands of Singkep, Bangka, and Billiton. The deposits of Nigeria and the Congo and most of those of China are also placers, but the Bolivian production is from veins, also referred to as lodes, as is that of the Cornwall, England, region (Fig. 314).

MALAYA. In general, granites form the mountain ranges, and these are flanked by metamorphosed sedimentaries which, in turn, are bordered by alluvial coastal plains. Deep and long-continued weathering of the granites and metamorphics has led to the development of thick masses of residual mantle rock and to the deposition of alluvial materials in the valleys and in the coastal plain. Malaya has produced more tin than has any other country, and its reserves appear to be sufficient to support its premier position indefinitely.

INDONESIA. The placer deposits of the Malay Peninsula continue into the islands of Bangka, Billiton, and Singkep in Indonesia, including even some undersea deposits around those islands where old stream valleys continue below the present sea level (during the Ice Age the sea level was considerably lower). Indonesia has supplied about one eighth of the world's tin in recent years. Existing resources are quite considerable, but production has been declining in recent years.

BOLIVIA. The tin deposits occur along the ranges east of the high plateau of Bolivia, in the area from Oruro to Potosi and from there southward to the Argentinian border. The ore bodies are again associated with granite and related intrusions into adjacent rocks. Production comes from ore bodies that require mining of hard rocks and is largely a development of the twentieth century. The mines are at elevations of from 12,000 to 20,000 feet, and conditions of exploitation are therefore severe. Difficult transportation conditions are another handicap. Although the peak of production was reached in 1929, the demands of World War II led to a second high of over 42,000 long tons in 1945. Since that time production has declined to less than half. Cost of production is rather high, but the extent of the ore reserves, known and potential, is such as to promise continued mining for decades to come.

ENGLAND. Tin has been produced in the Cornwall district since prehistoric times. Trade in Cornish tin was carried on by the Phoenicians, by the Romans, and later by the British themselves. Current production is less than 1 per cent of the world's total, but it is largely due to this early tin industry that the United Kingdom is now a major center of tin smelting, and London is one of the principal trading centers for tin.

Other areas. The Nigerian deposits are located in the Bauchi or Jos Plateau area, in the central part of the country; those of the Congo in the Katanga and Lake Kivu areas, as well as in adjacent Rwanda and Burundi. Much of the Chinese tin comes from Yunnan. Russian tin deposits are largely in the Amur region.

Most of the ore mined in Malaya and in Indonesia is reduced to metallic form in smelters in Singapore and on the island of

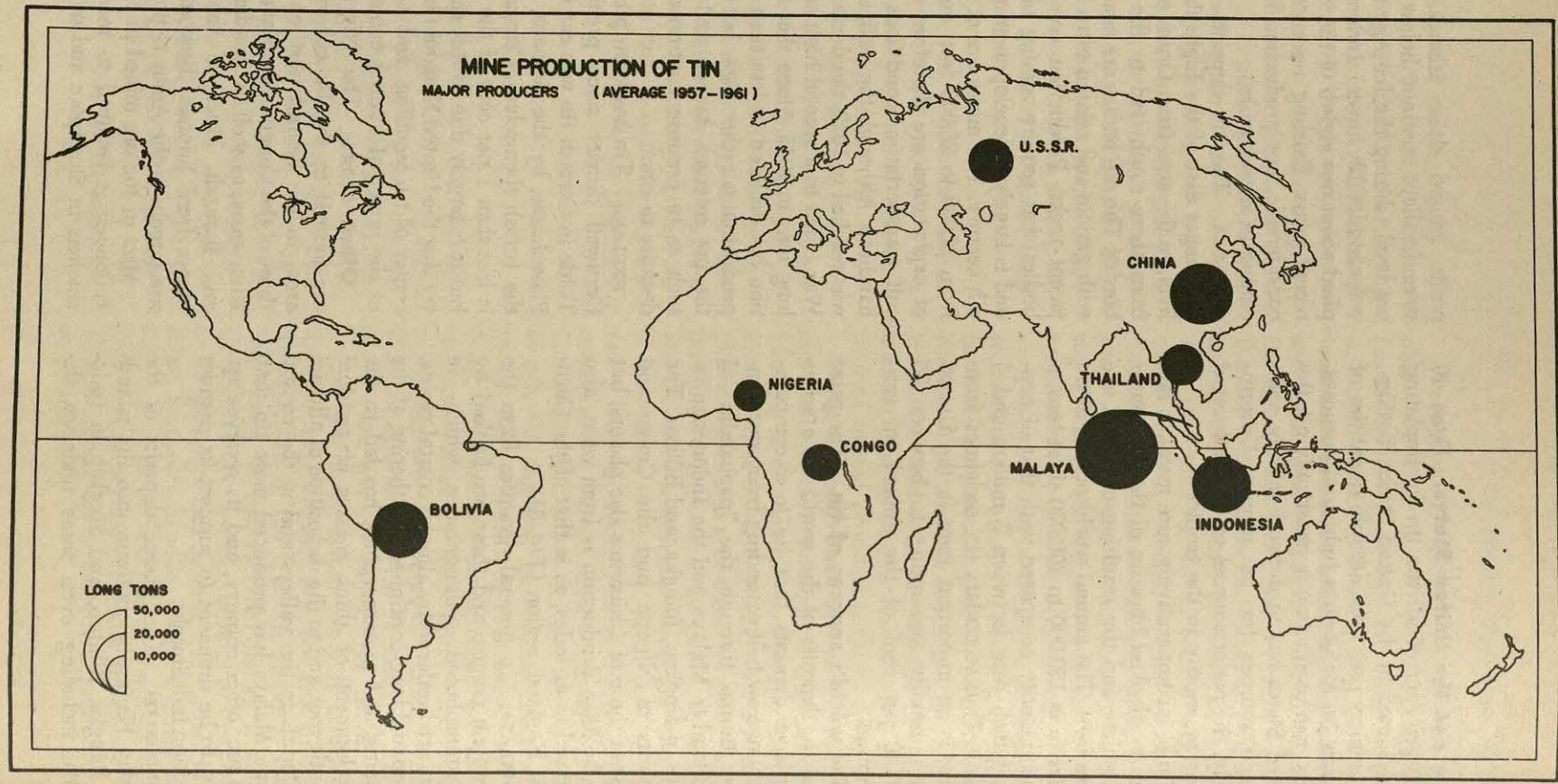

MINE PRODUCTION OF TIN
MAJOR PRODUCERS (AVERAGE 1957–1961)
U.S.S.R.
CHINA
THAILAND
NIGERIA
CONGO
MALAYA
INDONESIA
BOLIVIA
LONG TONS
50,000
20,000
10,000

Figure 314.

Bangka, whereas the ores mined in Nigeria are concentrated near the mines and are then shipped to smelters in Liverpool and in Redruth, Cornwall, England, to be converted into refined tin. Through ownership and operation of the smelters, much of the production of primary tin has long been controlled by British capital interests. In the United States a tin smelter is in operation in Texas City, Texas, to take care of Bolivian and other such concentrates as may be sent to it for conversion into refined tin.

Outlook for the future. Since tin is essential in the manufacture of war machinery and munitions, the Western world during World War II, with access to southeastern Asia cut off, had to depend heavily upon South America and Africa. The 1942 production peak in Bolivia, mentioned above, is readily explained by these needs, particularly of the United States. Great Britain drew heavily on Nigeria and the Congo.

Prospecting during the past two decades has indicated possibilities of important tin ore bodies in Africa, the Soviet Union, China, and elsewhere. Further exploratory work undoubtedly will be pushed vigorously whenever market conditions warrant, and thus additional valuable reserves may be found. However, for many years to come Malaya and Indonesia are likely to remain major sources of primary tin.

Much of world production has been controlled by the International Tin Council, operating an international tin agreement under the auspices of the United Nations. This situation appears likely to continue.

ALUMINUM

Despite the fact that scientists had been working for a number of years to devise means of producing aluminum in commercially usable quantities, as late as 1890 the metal was referred to as a curiosity; the cost of extracting it from the ores was so great that it had no industrial importance. The price was then more than $2.00 a pound (which, with the presently much lower value of the dollar, would now be at least $6.00) while in recent years it has sold at about $.25 per pound. Thus aluminum, in comparison with copper, lead, and zinc, came into use only yesterday, so to speak.

Uses of aluminum. Within the short time that it has been available, aluminum has outgrown some of its older sisters. Present world production of aluminum is around 5 million short tons; that of copper, around 4 million; of zinc, around 3.5 million and of lead, around 2.5 million. The record is even more impressive if we keep in mind that the specific gravity of aluminum is only 2.7, while that of copper is 8.9, of zinc 7.1, and of lead, 11.3. In other words, by *volume* the production of aluminum is now about four times that of copper.

The properties of aluminum that give it high industrial value are lightness, strength, electrical conductivity, and resistance to corrosion.

The pure metal is comparatively soft and ductile, but where fused with other metals the resulting alloy may have qualities comparable with those of structural steel. Elements commonly used in commercial alloys of aluminum are silicon, copper, and nickel.

Aluminum and its strong alloys have entered into the construction of railroad equipment, freight containers, commercial truck bodies, ships, airplanes, and automobiles. In recent years they have even entered the realm of heavy construction in the form of structural metals for bridges and large buildings. From the standpoint of quantity of aluminum used, the foundry and metalworking industries rank second to the manufacture of construction equipment. The electrical-appliance industry is third in importance. It has been expanding rapidly in late years because of the use of aluminum for electrical conductors for high-tension transmission lines, where aluminum steel-reinforced cables are standard construction. Substantially reduced costs of manufacture have placed aluminum ware within the reach of nearly all households and have opened up huge markets for such products.

Mode of occurrence of aluminum. Aluminum is one of the most abundant elements in the earth's crust, but ordinarily it does not exist in a form that makes extraction easy. It is a constituent part of many

of the rock-forming minerals, such as the different types of feldspar, the micas, and hornblende, and occurs in such products of rock alteration (metamorphism and other processes causing changes in rocks) as chlorite, kaolinite, and allied clay minerals. Unfortunately, although clays occur all over the world, their aluminum content is too low, and the presence of silica further hinders exploitation.

Bauxite. The present source of aluminum is not a pure mineral, but a claylike mixture of several hydrous oxides of aluminum, i.e., substances consisting of aluminum, hydrogen, and oxygen. It results from deep weathering of bedrock and residual mantle rock under warm, and rather moist conditions, preferably on extensive subhorizontal surfaces of the type often referred to as *peneplains*. The significant aspects of the processes that result in the formation of lateritic soils and outright laterites are the gradual removal of silica and the resulting gradual enrichment in iron and aluminum hydroxides (see p. 125). If there is little iron, the end product will be a combination of aluminum hydroxides, called bauxite. It is clear, of course, that a rather low silica content of the original rock helps greatly in the formation of bauxite.

Many of the bauxite deposits exploited at the present time are located in tropical and subtropical regions and were formed during comparatively recent geologic time (Tertiary). Some are found in areas where, in the geologic past, the climate was warmer and more moist than it is today. This is true, among others, for the Arkansas bauxite deposits and for those in southern France, Hungary, and Yugoslavia. In North America no bauxite is exploited north of the Arkansas deposits (less than 35° N.), while in Europe most of the deposits lie in the Mediterranean area.

Economic content of bauxite is usually stated in percentage of aluminum oxide or alumina (Al_2O_3), which may run from over 60 to near 50 per cent. In many cases, although there may be considerable overburden, the bauxite may be sufficiently close to



Fig. 315. Surface strip-mining of bauxite in Jamaica. A dragline excavator is used for loading purposes.

Courtesy Embassy of Jamaica

the surface that it can be mined by the low-cost open-pit method. In some areas underground mining has had to follow open-pit mining, as shallow deposits became exhausted; this is another example of the rising-cost trends in mineral production resulting from exploitation proceeding from the more-easily accessible to the less-easily accessible ores. In some other areas the bauxite beds were found to be so disturbed and set at such angles, that underground mining had to be practised from the beginning (Fig. 315).

By far the largest part of the bauxite mined is used for its aluminum content. In the United States this is well over 90 per cent. The remainder enters into the manufacture of abrasives, chemicals, and refractory materials.

Conversion of bauxite into aluminum. Bauxite is bulky and of low value in proportion to weight; hence it is desirable to remove most of the moisture and impurities, particularly if long and expensive haulage is necessary. Thus, for example, bauxite shipped from the Guianas to the United States Gulf ports is dried, but that imported from Jamaica, which is closer, is not.

The dried ore is often shipped long distances for the next step in the manufacturing process, the removal of remaining silica and the isolation of the alumina (Al_2O_3) by the so-called Bayer process. Alumina plants in the United States are located along the coast in Louisiana, Texas, and Alabama to take care of imported ore, and two are located in Arkansas for treating domestic ore. The aluminum in alumina is separated from the oxygen by electrolytic method, and thus the "reduction plants" are located where cheap electric current is available in suitable quantities. The roughly two dozen reduction plants in the United States are scattered over 13 states, 5 being in the state of Washington, which has considerable water power. Two are at Massena, New York, on the St. Lawrence power development, while another well-known site is that of Alcoa, Tennessee, within the Tennessee Valley Authority. Canada does not produce any bauxite, but it has several reduction plants located on important water-power developments, such as Shawinigan Falls on the St. Maurice river and Arvida on the Saguenay river, both tributaries of the St. Lawrence. Similarly, Norway, without bauxite deposits, is a large producer of aluminum due to its abundance of hydroelectric power (Fig. 316).

United States sources of bauxite. In the United States bauxite production is centered in a belt located just to the southeast of a line from Little Rock to Hot Springs, Arkansas. A small percentage of total production comes from Georgia and Alabama. Consumption of bauxite far exceeds domestic production. In recent years it has been from 3 to 5½ times as large. Thus the country must rely very largely upon imports from the Antilles and northern South America.

Bauxite production outside the United States. At present the major producers are located in the Antilles and northern South America. Within a comparatively brief time, Jamaica has become a major producer. Much of the ore lies practically at the surface, and distances to the coast are short so that cost of production is low. Haiti and the Dominican Republic produce smaller quantities. In South America production is centered in Surinam and in British Guiana. Both are part of a large area of old igneous and metamorphic rocks, called the Guiana Shield, which stretches into Brazil and French Guiana on one side and into Venezuela on the other. Throughout this area conditions have been favorable to the formation of bauxite, and thus it is likely that other valuable deposits will be found. In Africa there is at present significant production in Guinea and in Ghana. Also, in this part of the world further discovery of worthwhile deposits may be anticipated. The major European producers are France—the oldest of all—Hungary, Yugoslavia, and Greece. In Asia bauxite is produced in appreciable quantities in Malaya, Indonesia, Sarawak, and India. Russian production is based partly on domestic sources of aluminum but also on bauxite imported from Greece. The paucity of domestic bauxite has forced the Soviets to utilize nepheline and alunite as well, but their share in aluminum production is not known (Fig. 317).

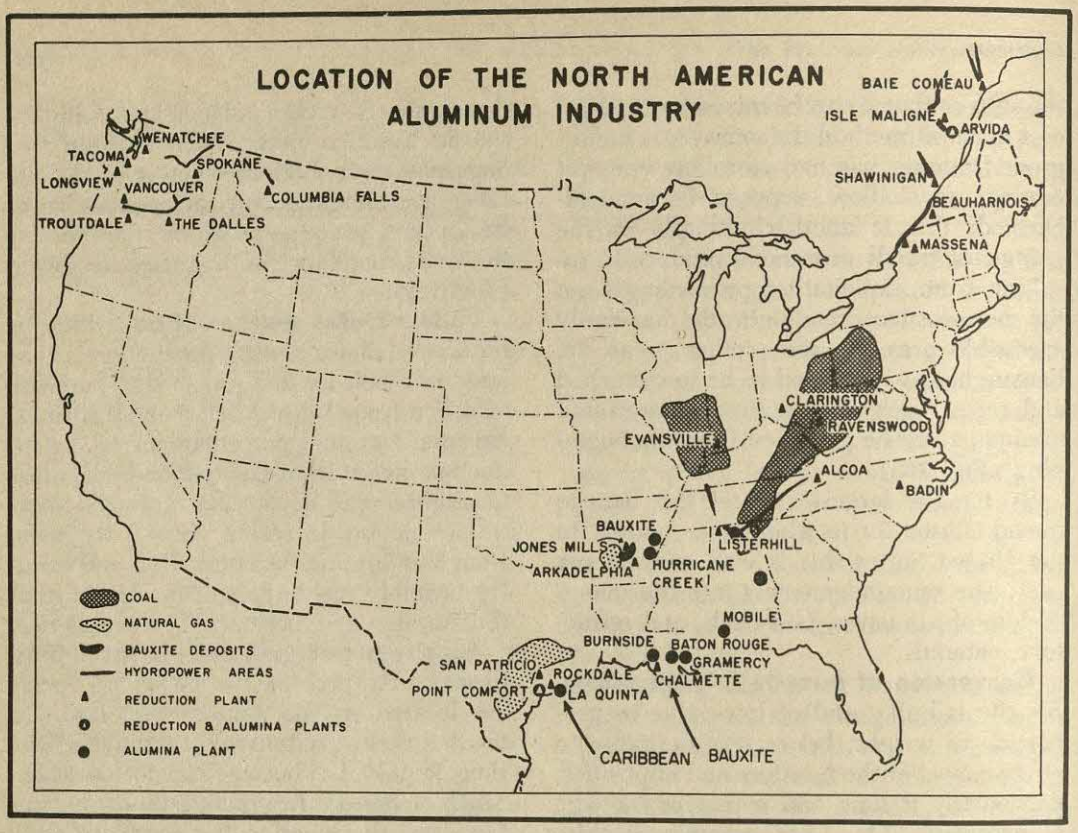
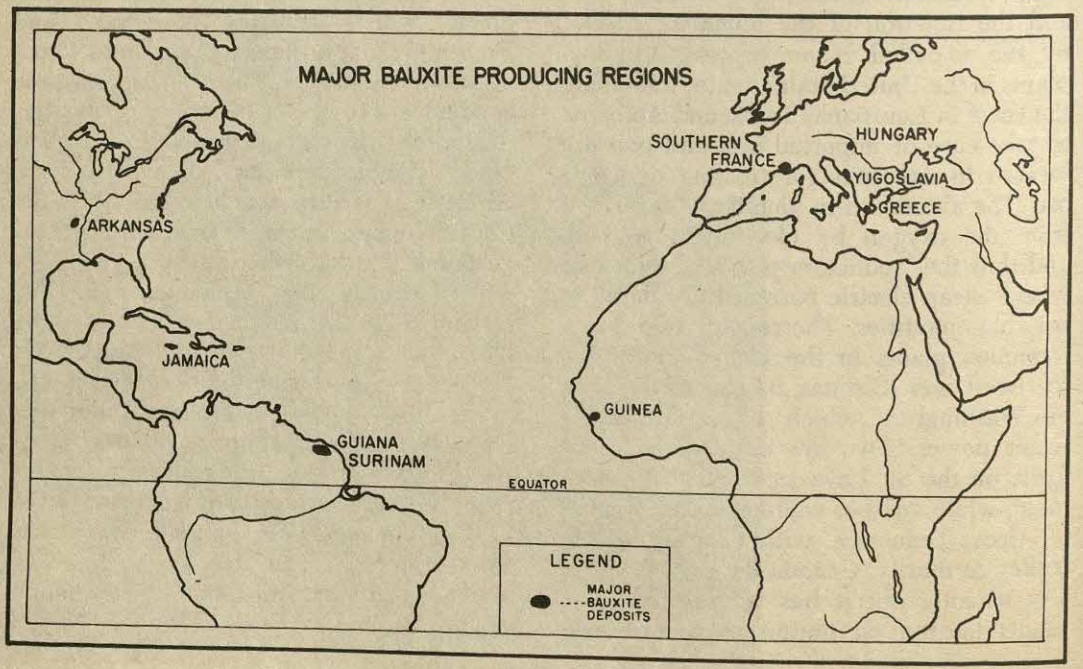


Figure 316.

Figure 317.



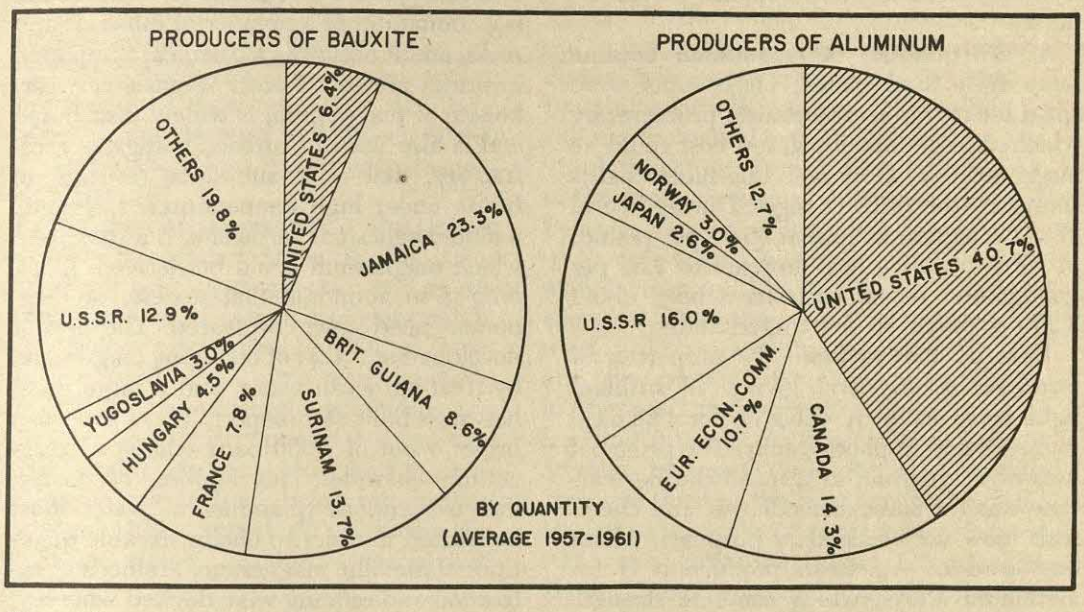


Figure 318.

The chief bauxite deposits are found in the central and southern Urals and in Leningrad oblast; nepheline deposits are located in the Kola Peninsula and eastern Siberia, and alunite deposits occur in Azerbaidzhan. Major aluminum refineries are associated with low-cost hydroelectric power produced on the Dnepr and Volga rivers and in the northwestern European part of the USSR, and with low-cost thermal electricity generated from brown coal in the central Urals and western Siberia (Krasnoyarsk area). Large-scale hydroelectric-power development in eastern Siberia has resulted in recent initiation of aluminum production in the Irkutsk region.

Future outlook. The large supplies of ore which are known to exist, the improvements in the methods of extraction, and a multitude of new uses make the outlook for the aluminum industry promising indeed. The tremendous expansion of the aircraft industry and the demands for strength, speed, and lightness in transportation equipment on land and sea seem to assure rapidly expanding markets now and in the future.

MAGNESIUM

Magnesium is nearly as plentiful in nature as aluminum, taking rank as the third most abundant metal. However, it has been difficult to find means of economically isolating the metal from the other elements with which it occurs in many combinations in the lithosphere and the hydrosphere, and it has come into use only comparatively recently. The total amount of primary magnesium produced in the world today is only a small fraction of that of copper and aluminum. In fact, on the basis of present-use characteristics it might be considered as primarily an aluminum alloy metal. Thus in this chapter it logically follows the discussion of aluminum. It is the lightest of the metals used for structural purposes, with specific gravity of only 23 per cent that of iron and 64 per cent that of aluminum. This results in a high strength-weight ratio that makes magnesium useful in construction when great strength in proportion to weight is demanded, as in the case of aircraft. Magnesium was first derived as a pure metal by Robert Bunsen, a

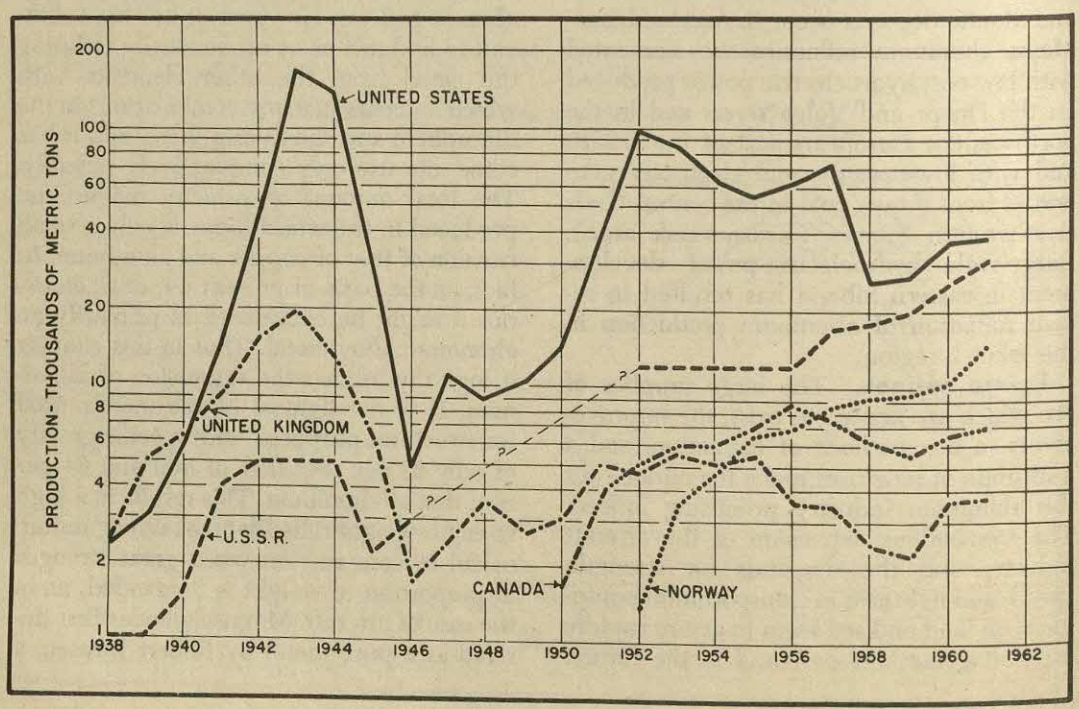
German chemist, in 1852, and its early production on an industrial basis occurred in Germany in association with the potash industry.

As the qualities of magnesium became more fully appreciated, large sums were spent for research on technical processes by which mass production at low cost could be made possible. How well this succeeded is shown by the price changes. During World War I magnesium sold at $5.00 per pound; in 1928 the price had dropped to $.55 per pound; and recent costs have been about $.35 per pound in the United States.

Uses of magnesium. Its properties of oxidizing readily and giving off brilliant light early made it valuable for chemical purposes and in photography. The principal uses of magnesium as a metal during wartime was for flares, incendiaries, and chemicals, now very secondary purposes. About one third of American production is for aluminum alloys, which combine strength and low weight, and another one third for structural magnesium products such as castings, sheets, plate, and extrusions.

Occurrence of magnesium. Magnesium is a compound of a number of minerals and rocks, and it occurs as a chemical compound in brines and sea water. Magnesite, a carbonate of magnesium, is widely distributed and is also used in furnace linings as a refractory, that is, a substance resistant to fusion under high temperatures. Dolomite, a lime-magnesium carbonate, is a rock from which magnesium could be derived. Dolomite is so abundant that scarcity of magnesium need never be feared. The newest development is that of obtaining magnesium by treating ocean water, and a large plant has been built at Freeport, Texas. In ocean brines 4 out of 1,000 parts consist of magnesium chloride. This implies, of course, that tremendous quantities of water must be treated in order to obtain sizeable quantities of metallic magnesium. Methods of extraction and refining were devised whereby, from these several sources, the production

Fig. 319. Magnesium. Annual production since 1938 of each of the principal producing countries of the world. The importance of magnesium as a wartime metal is graphically depicted for the period 1940-1945, and its increasing importance as an industrial metal is shown by the curves since 1946.



of magnesium in the United States expanded at a phenomenal rate during the early years of World War II from 3,350 short tons in 1939 to a peak of over 180,000 in 1943.

War demand largely resulted from extraordinary needs for the production of aircraft and incendiaries. Since that time production has dropped to between 80,000 and 40,000 short tons of primary magnesium (Fig. 319).

Production of magnesium in the United States. The United States is the major producer of primary magnesium and an important producer of magnesium compounds. Production of magnesite ($MgCO_3$) is, however, only from 12 to 7 per cent of the world total. Crude and processed magnesite and magnesia (MgO) are imported from Austria, Greece, and Yugoslavia. More and more of the production is from brine rather than from ore. Other important producers are the Soviet Union, Norway, Canada, and Italy.

To meet the need for strong- and lightweight materials for transportation on land and in the air, magnesium serves a highly useful purpose. With improved methods of production and techniques of manufacture, it seems certain to increase in importance as an industrial metal.

LEAD AND ZINC

Lead and zinc commonly occur together in nature. Sometimes a mining area produces more lead than zinc, sometimes it is the other way around. (See Fig. 320.) Even where only one of the two is produced commercially, usually small quantities of the other also are found. Both metals have been used for centuries, and lead has been mined as such for over two thousand years. The latter metal was used by the Romans for plumbing purposes.

Uses of lead and zinc. The two metals differ considerably insofar as their chemical and physical properties and their uses are concerned, but they have in common that their uses are manifold, and that they are both indispensable to our modern machine economy.

The properties which make lead valuable are its softness, malleability, and resistance to corrosion. It can easily be rolled or hammered into sheets but, unlike copper or iron, it lacks ductility—that is, it cannot be drawn out into fine thread or wire. Its resistance to corrosion makes it exceptionally valuable for plumbing fixtures, storage batteries, and for cable, widely used in the telephone and telegraph industries. Since lead is the only one of the common metals which is not affected by sulfuric acid, it is used in construction of linings of all kinds of apparatus for the manufacture of this important industrial chemical. For many years more lead was used in the manufacture of paints than for any other purpose, but as a result of changes in the paint industry the consumption of lead in that field has decreased materially. Storage batteries generally take slightly over one third of the lead consumed in the United States, the manufacture of tetraethyl and tetramethyl lead for gasoline, about 15 per cent, and that of pigments, about 10 per cent. The remainder is used for a great multiplicity of industrial purposes. There is an increasing demand for lead for nuclear work and radiation shielding. The importance of the automobile in the American economy is eloquently illustrated by several of these uses.

The properties which make zinc particularly valuable are its ability to enter into alloys and its resistance to oxidation. Nearly half of the zinc used in the United States enters into the manufacture of various types of alloys with a zinc base, and various brass products and light-metal alloys; slightly over 40 per cent is used in galvanizing.

The process of covering sheet iron or steel with a thin coating of zinc is called *galvanizing*. Iron sheets so treated resist rust, and thus their life is greatly prolonged. Brass is an alloy of zinc and copper in various proportions, but ordinarily it consists of from 66 to 83 parts copper and 34 to 17 parts zinc.

The ores of lead and zinc. The principal mineral that contains lead is galena, a combination of lead and sulfur. There are many other lead minerals, but most of them are the result of chemical alterations starting from galena. The mineral can be recog-

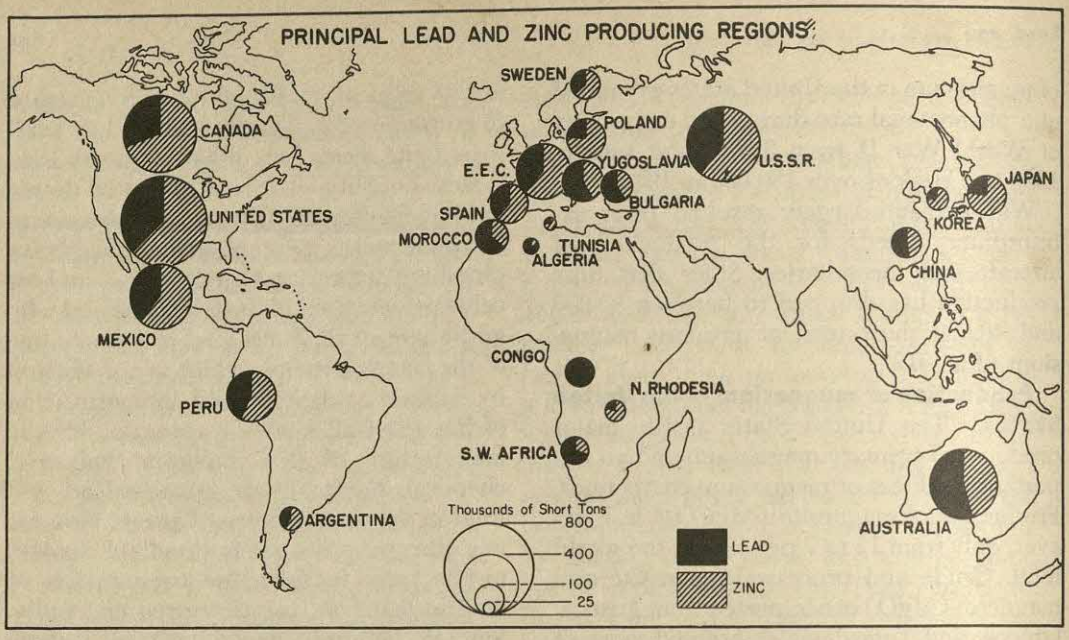


Figure 320.

nized by its weight (86.4 per cent is metallic lead) and its tendency to occur in regular cubic crystals. As mined, galena is associated with much gangue material and also with the minerals of other metals, especially of zinc, and it may contain silver, antimony, gold, and other metals. It is therefore difficult to give a representative figure for lead content of ores. In addition, there are deposits in which the galena is disseminated, i.e., scattered in small, individual bits through large masses of rock, such as limestones, and there are others where the mineral occurs in more concentrated form in veins or lodes. Nevertheless, in most cases it is necessary to concentrate the ore so as to raise its metal content before it can go to the smelter.

The major zinc mineral is sphalerite (zinc-blende), a combination of zinc and sulfur. As in the case of lead, the other zinc minerals are probably derivations of sphalerite. Other metals may also be found in sphalerite, such as cadmium and gold, and it may be associated with galena. Zinc content of ores generally ranges from 2 to over 12 per cent, again generally necessitating concentration before further treatment.

Geographic distribution of lead production. Lead ore is fairly widely distributed in the world, every continent having deposits of present and potential value. However, major producers are not as numerous. Among these rank Australia, the USSR, the United States, Canada, Mexico, Peru, Yugoslavia, and Morocco (Fig. 320).

UNITED STATES. In recent years the United States has produced from 10 to 14 per cent of the world total of lead mined, but it has refined considerably more, from 15 to about 20 per cent, due to large imports. The foremost lead-producing center is located in southeastern Missouri, where mining has long been in progress. Ranking next in importance is the Coeur d'Alene region of Idaho. Other centers of significant production are located in Utah, Colorado, Washington, and Arizona (Fig. 321).

Mine production of lead in the United States has shown a tendency to decline during the last three decades and now covers only about one fourth of consumption. Fortunately, much lead can be recovered for reuse in industry. The amount of secondary lead so made available is well over 1½ times as large as mine production. Nevertheless, much lead must be imported, imports considerably exceeding mine production. Two major producers are located nearby, Canada and Mexico, but much lead comes from as

far away as Peru, South Africa, Yugoslavia, and Australia.

MEXICO. Prior to 1913, Mexico had become an important producer. Since that time the trend has been upward, and the country has taken fourth place among producers, with output of generally over 200,000 tons per year. The lead industry of Mexico is financed in large measure by American capital, and from half to one third of the exports are sent to the United States.

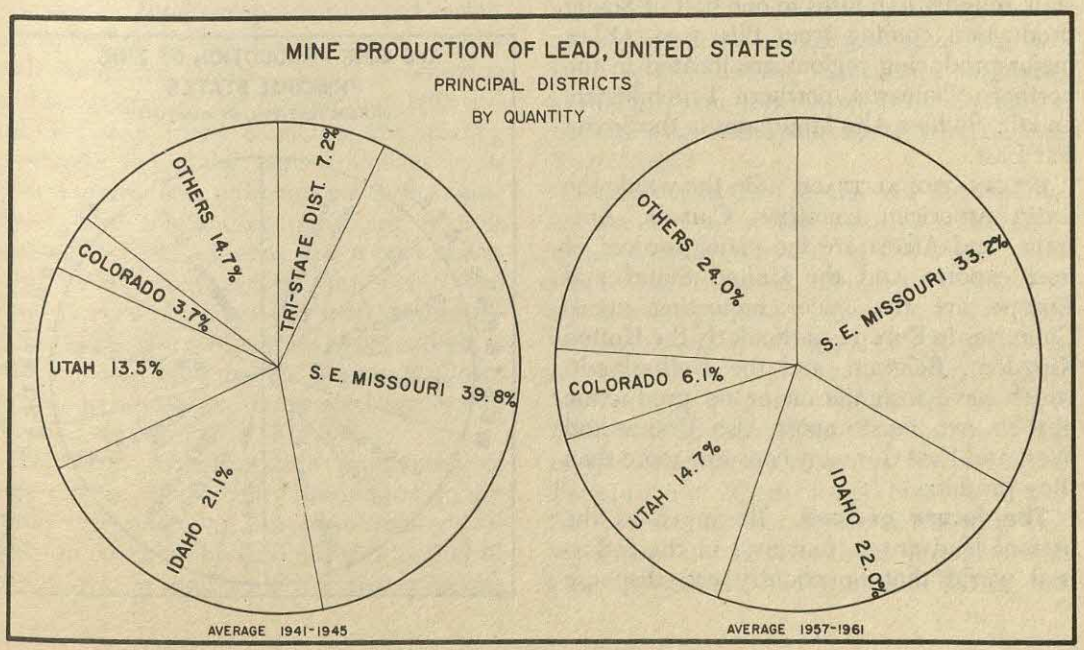
CANADA. The greater part of production is located in the mountains of southeastern British Columbia, with other mines located in the Yukon, in Newfoundland, and a few other areas. Canada has the advantage of large capital resources from Europe and the United States and of intimate commercial relations with the other parts of the British Commonwealth. Furthermore, cheap power is available in the producing areas, a factor highly favorable to the mining and smelting operations. Ore reserves sufficient for lead production at the rate of from 180,000 tons to 200,000 tons per annum for 25 years are claimed to have been proved. If further exploratory work should demonstrate this to be the case, Canada will undoubtedly hold its place as one of the important lead-producing countries (Fig. 322).

OTHER WESTERN HEMISPHERE PRODUCERS. The only other major lead producer in the New World is Peru, which normally exports an appreciable portion of its production to the United States. Minor producers are Argentina (in Jujuy and San Juan provinces) and Bolivia (Oruro area).

EUROPE. Total production of lead in Europe (minus Russia) is quite large, always exceeding that of the United States, and in some years more than twice as large. Production, however, is spread over a number of countries, of which the major ones are Yugoslavia, Bulgaria, Spain, Sweden, West Germany, Italy, and Poland.

AUSTRALIA. Australia has been an important lead producer for a number of years and has recently occupied first place among lead-producing nations. There seems to be no question that ample ore reserves exist, the principal ones having been reported in the Mount Isa area of northwestern Queensland and in the Broken Hill area of New South Wales. Australia seems assured of

Fig. 321. Changes in lead production in the United States. Note the disappearance as a producer of the Tri-State district, near Joplin, Missouri, and Galena, Kansas, formerly an important mining area.



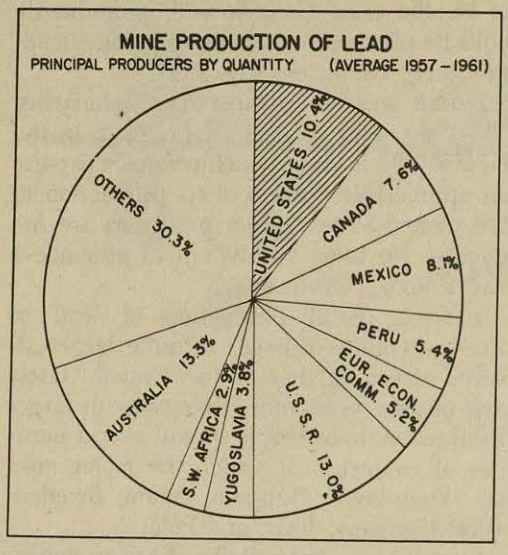


Figure 322.

continued importance in lead production.

OTHER PRODUCING AREAS. While lead is mined in a number of Asiatic countries, total production of that continent is comparatively small and is always considerably exceeded by African production, the major contributors to which are Morocco and South-West Africa. In the Soviet Union the most important regions of production are the foothills of the Altai Mountains in eastern Kazakhstan, roughly two fifths to one half of Soviet production coming from this area. Other major producing regions are located in the northern Caucasus, northern Tadzhikistan, and the Sikhota Alin Mountains in the Soviet Far East.

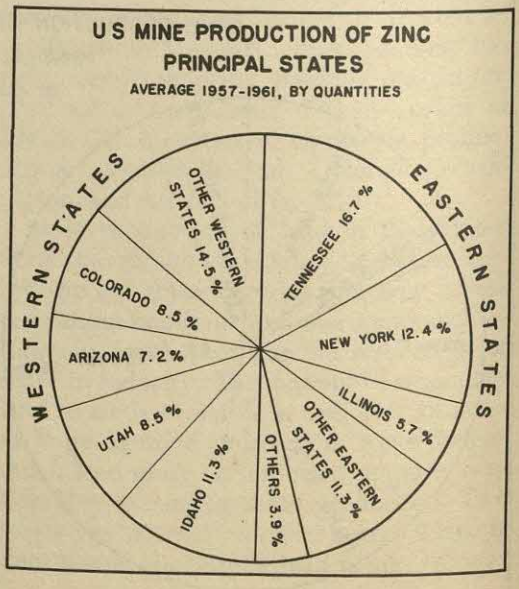
INTERNATIONAL TRADE. On the whole the Latin American countries, Canada, Australia, and Africa are the major sources of lead exports, and the United States and Europe are the major importing areas. Countries in Europe, particularly the United Kingdom, Belgium, and the Netherlands, which have insignificant or no production of their own, must import. Also, France and West and East Germany consume more than they produce.

The future of lead. Inasmuch as the uses of lead are so universal in the industrial world that no country can dispense with this metal, the present situation in foreign trade is not likely to undergo any radical change in the near future.

Geographic distribution of zinc production. As has been mentioned above, zinc commonly occurs in association with lead, and as a result the geographical distribution of zinc shows a fairly close resemblance to that of lead. However, the quantities of zinc produced differ from those of lead. Nevertheless, the six major producers of zinc—the United States, Canada, the Soviet Union, Australia, Mexico, and Peru—are the same as the six major lead producers, though not quite in the same order.

UNITED STATES. The United States is still the leading producer of zinc in the world. The so-called Tristate district, near Joplin, Missouri, and embracing small portions of northeasternmost Oklahoma and adjacent Kansas and Missouri, was for many years the foremost center of zinc mining in the United States, but has now faded into insignificance. The same is true of the formerly flourishing New Jersey mining area, both regions being excellent examples of the more or less temporary character of many types of mining. At present Tennessee and New York are the principal producers of

Figure 323.



zinc. In the Rocky Mountains zinc is found in complex ores which also often contain lead, silver, and gold. Idaho, Utah, Arizona, and Colorado are the states leading in production in this area. There are a considerable number of other areas that produce zinc, but the quantities involved are smaller (Fig. 323).

The annual production of recoverable zinc in the United States during the past decade has ranged from about 400,000 to 600,000 tons. Although the United States is the major zinc producer of the world, it still imports large quantities for its own consumption, primarily from Canada, Mexico, and Peru. Production of secondary zinc in the United States is also important and usually amounts to over one sixth of total consumption.

OTHER WESTERN HEMISPHERE PRODUCERS. The major portion of Canadian zinc is produced in the same section of British Columbia where most of the lead is also mined. Considerable quantities of zinc are produced by copper mines in western Quebec near Lake Abitibi, in the Flin Flon area on the boundary of Manitoba and Saskatchewan, and in Newfoundland. In Mexico and Peru, the other two major producers in the Western Hemisphere, zinc is mined in essentially the same regions where lead is produced (Figs. 324, 320).

EUROPE. Total zinc production in Europe, not including Russia, is quite large, usually well exceeding United States production and sometimes almost double that. It is distributed over many countries, the leading producers being the same countries mentioned under lead, although not in the same order. The outstanding producing area is located in Upper Silesia, now a part of Poland, which produces much more zinc than lead. A very old zinc- and lead-mining region is the Harz Mountain area, which is still a major producer in Germany. Other producers of note in Europe are Italy, Spain, Sweden, and Bulgaria (Fig 320).

In North America mine production of zinc (in ore) and smelter production do not differ very much, but European smelter production considerably exceeds production of the mines. Several countries that produce

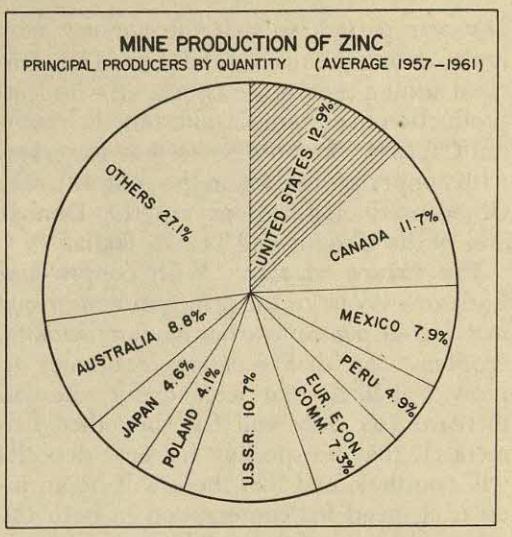


Figure 324.

no ore have important smelter production based upon imported concentrates and ores. Belgium is an outstanding example, with an old and well-established smelting-refining industry based originally upon the ores of the little Moresnet region of northeastern Belgium. As these are exhausted the industry must now depend entirely upon imports. The United Kingdom and the Netherlands also smelt only imported concentrates, while both France and West Germany smelt considerably more than they produce themselves. Imports come largely from overseas, from South America, Africa, and Australia, although some come from other European countries such as Spain, Italy, Sweden, and Yugoslavia.

OTHER PRODUCING AREAS. In the remaining parts of the world Australia is the principal producer of zinc, in the same areas where lead is mined, though production of the latter is generally somewhat larger than of the former. In Africa the Congo produces much zinc in the Katanga copper area. Morocco and South-West Africa are less important for zinc than they are for lead; on the other hand, the reverse is true for the Federation of Rhodesia and Nyasaland and for Algeria. In Asia, Japan is the principal producer. In the Soviet Union production of zinc has increased substantially during the

post-war period, so that the country now ranks among the major producers. The principal mining centers are associated with lead production in eastern Kazakhstan, the northern Caucasus, and the Soviet Far East, and with copper production in the central Urals. Other producing regions are the Donbas area of the Ukraine and Transbaikalia.

The future of zinc. With copper and lead, zinc is one of the principal nonferrous metals indispensable to our modern machine economy. As that economy continues to grow, it is likely that demands for zinc will increase (as they will for the other two metals), that prospecting for new deposits will continue, and that there will be an increasing need for conservation in both the mining and use of the metal.

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27

Important Rocks and Minerals of Direct Economic Use

In the preceding three chapters we considered the minerals that are important because they are the sources of metals that play a major role in our modern machine economy. In most instances the extraction of the metal concerned from the ore was seen to be a fairly difficult and complex procedure, requiring heavy investment in machinery and equipment and considerable technical knowledge. In this chapter we shall discuss certain minerals, and also rocks, that are suitable for industrial purposes without the necessity of conversion through complicated smelting or reduction processes, in other words, minerals and rocks of more or less *direct economic use*. There are many minerals in this group, but we must limit our study to those which occupy places of economic importance in the industrial scheme. On that basis major minerals and rocks in each of the following groups will be discussed:

(1) minerals and rocks that are primarily of importance for various types of construction purposes
(2) minerals of importance especially to the chemical industries
(3) important mineral ingredients in commercial fertilizers

ROCKS AND MINERALS OF IMPORTANCE FOR CONSTRUCTION PURPOSES

There are a number of common rocks and minerals which are usually extracted in such comparatively simple ways, and which are so plentiful and so well distributed geographically that the public is inclined to grossly underestimate their importance in the economy. During the years 1957-60, for example, the value of the production of bituminous coal and lignite in the United States fluctuated between about 1,950 and 2,500 million dollars, and that of copper between 500 and 700 million. During the same period the value of stone quarried fluctuated between 815 and 900 million dollars; of sand and gravel, between 600 and 730 million; of clays, approximately between 130 and 160 million; and of lime, between 120 and 175 million. The value of one of

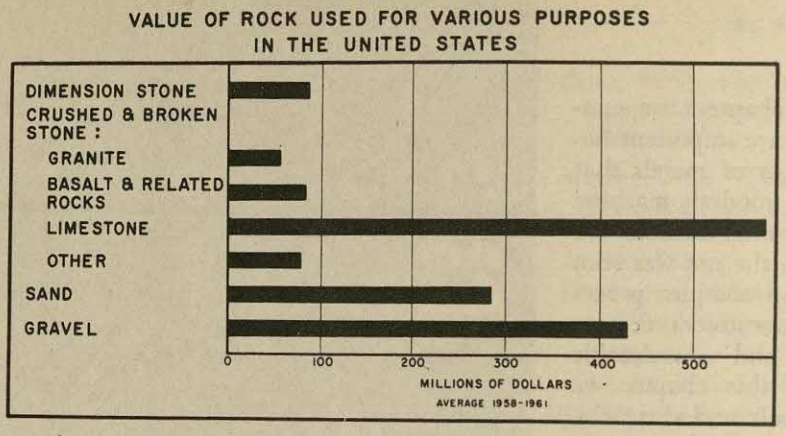


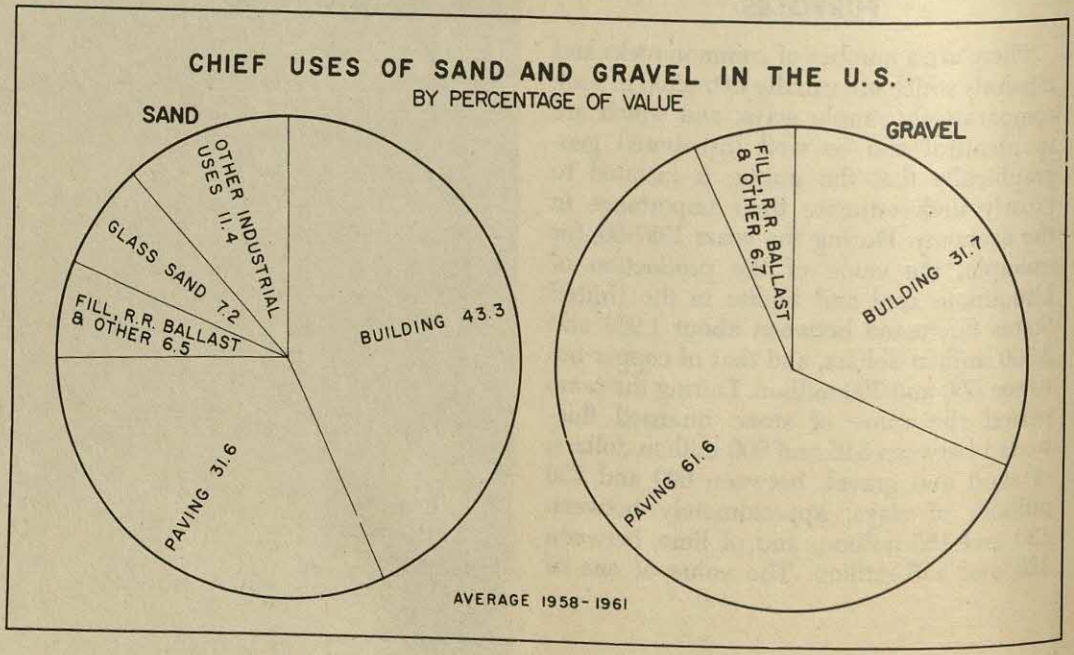
Figure 325.

the derivatives of stone, namely cement, fluctuated between 960 and 1,145 million dollars (Fig. 325).

Sand and gravel. Sand and gravel are well distributed throughout the United States and the world. These are not commodities in which there is any significant international or even interstate trade. They are of great bulk and low value per unit and can be transported economically over any considerable distance only by water. Floodplains, stream and lake terraces, coastal areas, and old coastal terraces are the most common sources for one, or the other, or both. A special product is glass sand. It must have a high purity, i.e., a quartz content of over 95 per cent, and while certain impurities are desired, others may make sands unsuitable for glass manufacture. Glass sands may be unconsolidated, but friable sandstones may also be suitable for use. In the United States glass sands are produced in West Virginia, Pennsylvania, Illinois, Minnesota, Missouri, and New Jersey (Fig. 326).

Clay. Clay in some form enters extensively into construction work and a large variety of manufactures. The total annual production of raw clay in the United States has varied in recent years from 40 to 50 million tons, reaching values of from 130 to 160 million dollars, as mentioned above.

Figure 326.



The importance of clay as raw material is clearly shown in the value of the various manufactured products. Brick, tile, and related products, used mostly for construction purposes, are far in the lead. Shipments of these "structural clay products" in the United States have in recent years fluctuated around a value of 500 million dollars. Brick and tile industries will probably increase in importance as wood for building purposes becomes scarcer and more expensive in the United States. There are, of course, many parts of the world where for centuries clay in various forms—from clay smeared on wattle, to sun-dried brick or adobe, to fired brick—has been the major constructional material.

Certain clays, so-called *fire clays*, are used for the manufacture of refractories, such as firebrick. Another kind, China clay or *kaolin*, is used as a filler in the manufacture of paper, in the rubber industry, and in the manufacture of pottery. *Pottery* is a term used rather loosely to cover the manufacture of earthenware varying from ordinary inexpensive flower pots to high-grade chinaware. Earthenware is porous and fired in the kiln at comparatively low temperatures, while chinaware (or vitrified ware) is almost nonporous and is fired at high temperatures. Between the two stands semivitrified ware. In the United States clay for the coarser types of pottery is plentiful, but until recently the domestic production of high-grade kaolin for use in the manufacture of chinaware was not large enough to meet the demand, and considerable quantities were imported, mostly from England. However, it has been found that domestic kaolins, when processed in a suitable manner, are as good as, and for certain purposes even better than, imported clays. Large reserves of kaolin exist in Georgia, North Carolina, South Carolina, and Florida. At present the principal producer is Georgia.

Although the United States produces much household chinaware, it also imports it, particularly tableware. In recent years the value of these imports has exceeded 20 million dollars. Major sources are Japan, which accounts for over half the imports, West Germany, and Great Britain. Imports from France, once fairly large, have dropped to only a small per cent of the total. Also, much earthenware is imported, largely from Japan and Great Britain.

Well-known china industries exist in a number of European countries: England, West and East Germany, Austria, France, and Denmark. Japan also is an important producer and exporter.

Marble. Marble is a metamorphic rock, but the trade applies the term to any calcareous rock capable of taking a high polish. Although pure marble is white, because of impurities and differences in structure it may vary in color from white to dark blue, green, and even black.

In the United States the states leading in production are Vermont, Tennessee, Georgia, and Missouri, their combined output accounting for about 80 to 85 per cent of the nation's total.

The most famous *statuary marble* in the world is quarried near Carrara, Italy, on the flanks of the Apennines. The quarries have been operated for centuries and have furnished raw material for much of the world's sculpture. The marble is uniformly fine grained, the color is snow white, and flawless blocks may be obtained large enough for any desired use. These qualities have given Carrara marble its fame and worldwide markets. The demand for marble as monumental stone is declining in the United States because of its deterioration under the influence of the weather and also as a result of its high price.

Granite. On the whole granites are durable, especially the finer-textured varieties. Most varieties are capable of taking a high polish and hence are in demand for monumental purposes.

Granites are fairly common. In the United States they are widely distributed in the crystalline portions of the Appalachian highlands, in the western mountain areas, and in northern Michigan and Minnesota (part of the Canadian Shield). There are immense stores of granite in the Canadian part of the shield, but commercial development has been slight because of the relatively small population, remoteness, and competition with other building materials.

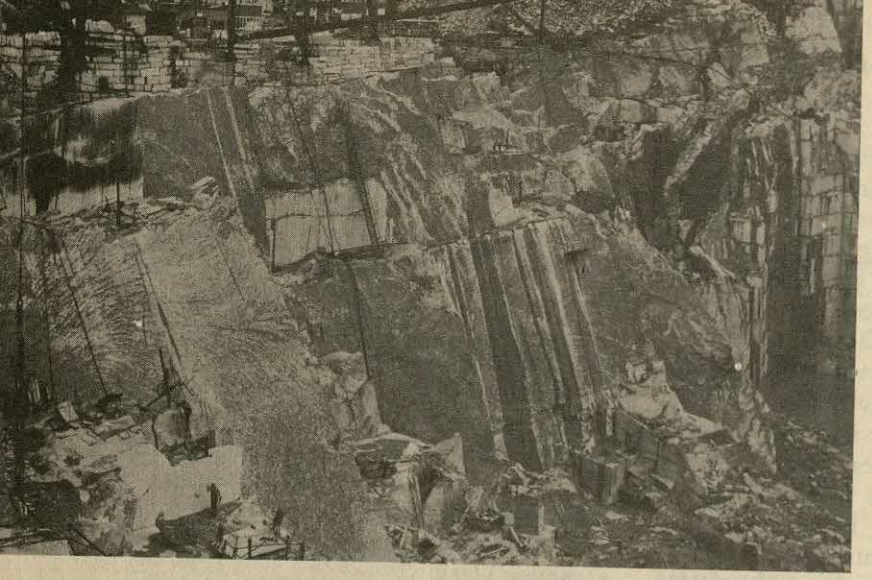


Fig. 327. View in one of the large granite quarries in the Barre district of Vermont. Note the blocks of even texture at left, and the evidence of banded structure near the middle at right. Size of operation can be inferred from men at work in lower left.

Courtesy Rock of Ages Corporation

In Europe, among others, the mountainous areas of Scotland and Norway and parts of the Scandinavian Shield in Sweden and Finland produce granites known for their beauty and value for monumental and other purposes.

Granite is produced in two forms: (1) in blocks for monumental and building purposes, and (2) in crushed or broken form. In the United States the total tonnage of crushed or broken granite produced far exceeds that used for monumental and building purposes, but the value of the latter is greater. The leading granite-producing states are Georgia, Minnesota, South Carolina, Maine, and Wisconsin. Barre, in central Vermont, furnishes a well-known monumental stone (Fig. 327).

Sandstone. The four outstanding uses for sandstone in the United States are: (1) as dimension stone; (2) for glassmaking, though for this purpose only comparatively pure sandstone can be used; (3) as crushed or broken stone for matrix in concrete work; and (4) for the manufacture of refractory tile and brick. The latter, known in the trade as *silica brick*, is used where material must be subjected to high temperatures without fusing. In the United States the state of Ohio, with Berea as the producing center, has undisputed leadership in the output of dimension sandstone. The sandstone production of Pennsylvania and Wisconsin is used largely for glassmaking or in the manufacture of refractory tile and brick.

Slate. The value of slate depends upon its well-defined planes of splitting, which make it possible to divide it into slabs or thin sheets that can be used as flagstones, for roofing, sanitary and chemical ware, and for blackboards. In preparing these slabs, however, the percentage of waste is high, sometimes running up to 80 per cent. A portion of this waste is used as granules on asphalt roofing. The states that lead in slate production in the United States are Pennsylvania, Vermont, Virginia, and New York.

Gypsum. Gypsum is *anhydrite* ($CaSO_4$), a mineral, plus a certain amount of chemically bound water. Both gypsum and anhydrite are the result of evaporation of salt water, as is halite or "kitchen" salt, but the former two are precipitated out much sooner because they are less soluble. Anhydrite is the most common cap rock of the so-called *salt domes*,* but it is little used industrially. Gypsum occurs in various forms. One is *alabaster*, used for ornamental work, another is the crystal form, *selenite*. The most common form is "gypsum rock," which occurs in beds or large lenses from a few feet to hundreds of feet in thickness, and which is more or less pure.

Gypsum rock may be used without any processing other than grinding, and considerable quantities are so used. Crushed or ground gypsum is used for agricultural purposes to correct the acidity of some soils;

* See the section on potash in this chapter.

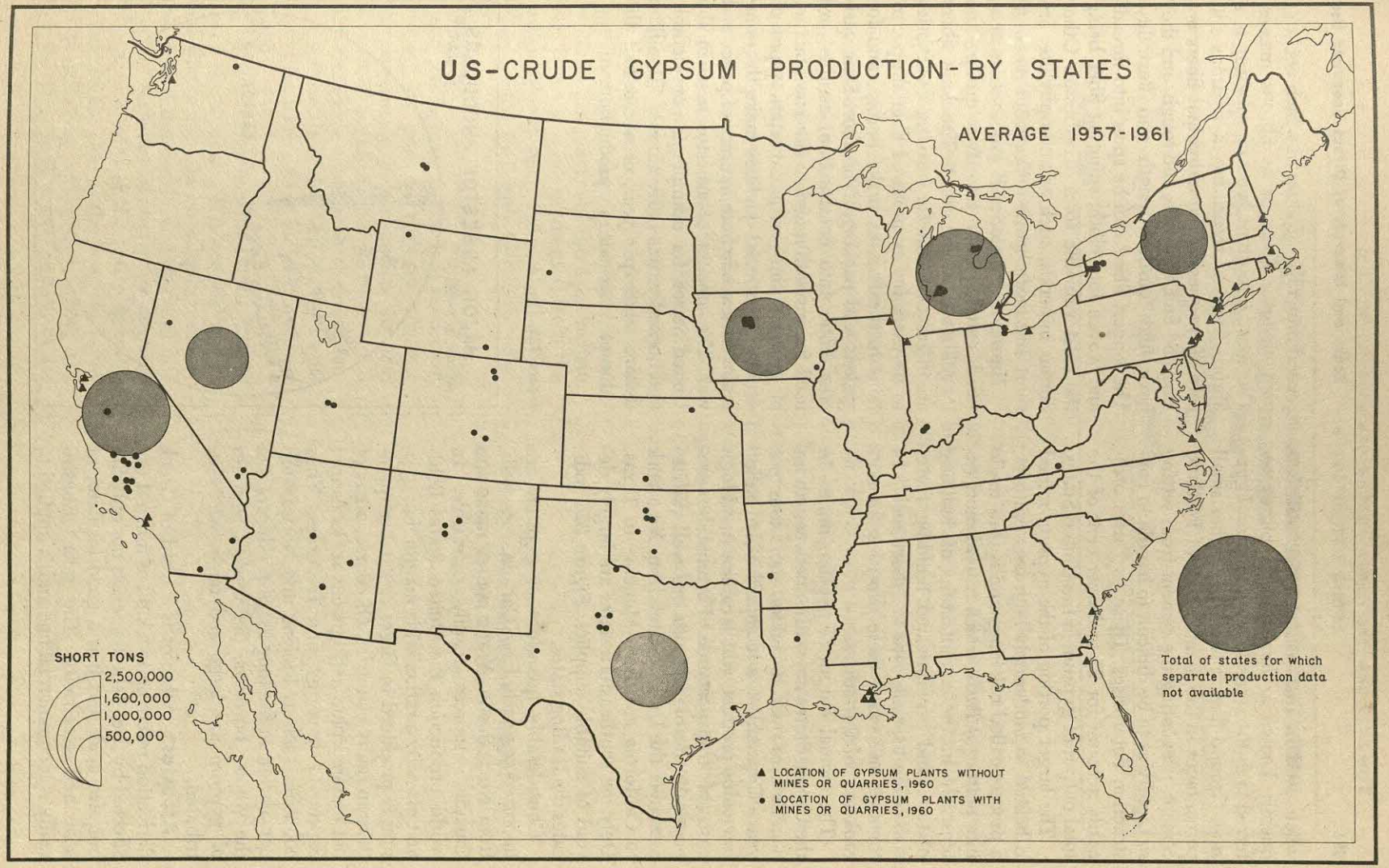

US-CRUDE GYPSUM PRODUCTION-BY STATES
AVERAGE 1957-1961
SHORT TONS
2,500,000
1,600,000
1,000,000
500,000
Total of states for which separate production data not available
▲ LOCATION OF GYPSUM PLANTS WITHOUT MINES OR QUARRIES, 1960
● LOCATION OF GYPSUM PLANTS WITH MINES OR QUARRIES, 1960

Figure 328.

when used in that manner, it is still frequently known as *land plaster*, but is referred to in the statistics as *agricultural gypsum*. Ground fine, it is used in rather small percentages in the manufacture of Portland cement, preventing the cement from setting so rapidly as to be difficult to handle in construction enterprises. These two uses ordinarily account for 25 to 30 per cent of the total output of gypsum in the United States.

The larger portion of the gypsum mined is heated to moderately high temperatures, a process called *calcining*, and is thus made into *plaster of Paris*, which is used most extensively in the manufacture of building plasters and prefabricated building materials, such as wallboard or "sheet rock." In tonnage and value these two uses far outrank any of the others.

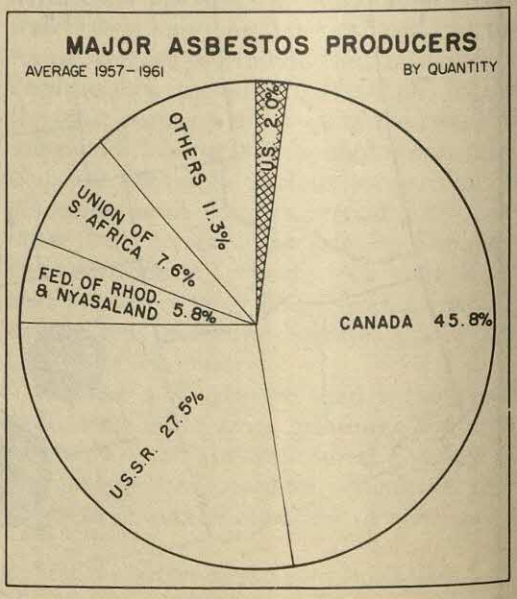
The annual output of gypsum mined in the United States now varies between about 8 million to over 10 million short tons per year. Gypsum is a comparatively bulky, low-value product, which cannot stand high costs of transportation. Fortunately, economically usable deposits are well distributed over the United States, from New York to California and from Montana to Texas. Only the southeastern states are largely devoid of suitable supplies. Figure 328 indicates the leading states.

Considerable quantities of gypsum are imported regularly from Canada, especially from Nova Scotia. Water routes make the Canadian sources readily accessible. In world production the United States holds first place by a rather wide margin, but gypsum is produced in larger or smaller quantities in many countries. Of course, areas of old metamorphic and igneous rocks cannot expect to have gypsum resources. Thus countries such as Finland and Norway are not present in the long list of producers. On the whole, however, the world's supplies of gypsum are large and fairly well distributed.

Asbestos. Asbestos is a word of Greek derivation referring to a kind of mineral unaffected by fire. Asbestos resists not only fire but also acid, and it is a good insulator of heat and electricity. The term asbestos really is a commercial one and is applied to several minerals, varieties of which occur as long, delicate fibers or as fibrous masses. The most important type of asbestos is a fibrous form of *serpentine*, a hydrous silicate of magnesia. The individual fibers are long and fine, infusible, and tough, and they have high-tensile strength and flexibility. The longest fibers can be spun into threads and woven into cloth, spinning fiber being the most valuable form of asbestos. Other fibrous minerals, such as anthophyllite, are short and more brittle and cannot be spun.

The several varieties of asbestos are classified commercially into two groups—the long fibers and the short. The long fibers are in great demand for weaving into fabrics to be used, for example, as fiber drop curtains in theaters, as brake linings, and for gaskets and packings. The short-fiber varieties enter into construction, as they are used for insulation and in the manufacture of asbestos shingles and certain types of cement. Its special qualities make this mineral a critical one both in times of peace and war. The amount of asbestos used in the United States, for example, is considerable and normally runs fairly close to 70 million dollars worth per year, or about half the value of American salt production.

Figure 329.



USES OF CRUSHED AND BROKEN LIMESTONE AND DOLOMITE IN THE UNITED STATES

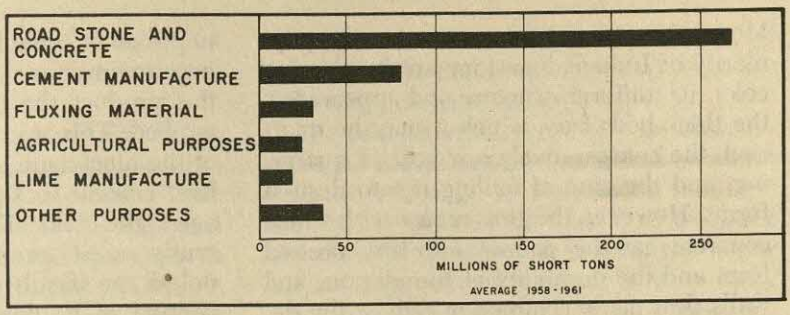


Figure 330.

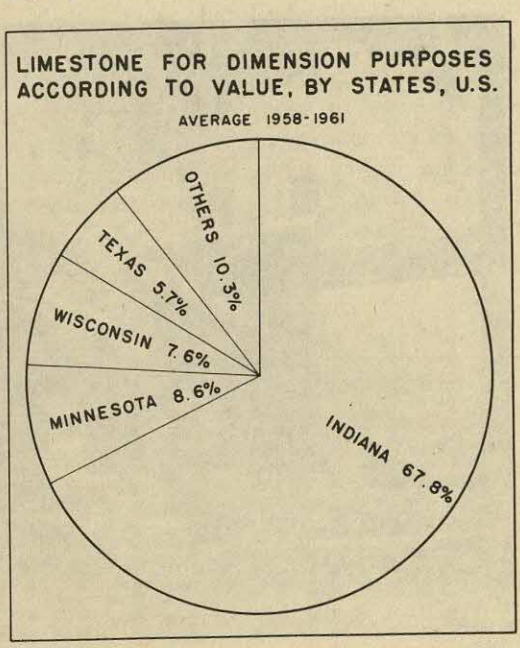
The United States has little asbestos. Unless new deposits are discovered, the country must continue to be dependent upon imports for its needed supplies because the present outlook is that not more than 5 to 10 per cent of the demand can be met from domestic sources. Fortunately, the world's major producer of asbestos is Canada, which ordinarily provides almost half of the world's supply and which furnishes 90 per cent of the asbestos imports of the United States. Other principal sources of asbestos are the Soviet Union, South Africa, and the Federation of Rhodesia and Nyasaland. In Canada most of the mining is in the Asbestos-Thetford region, which lies about 60 miles north of the northeastern corner of Vermont, in the province of Quebec, and which is part of the Canadian portion of the Appalachian region. There is some production from the Canadian Shield near Lake Abitibi, Ontario, and some in British Columbia (Fig. 329).

Limestone. Limestone is one of the common sedimentary rocks. It is used most extensively as crushed rock in concrete work, particularly in pavements, foundations, and in building construction and is the principal raw material in the manufacture of cement. It is also well known for its use as dimension stone for the walls of buildings.

PRODUCTION OF LIMESTONE IN THE UNITED STATES. The output of limestone in the United States has shown a rather steady increase for a number of years, and of late this type of rock has accounted for approximately three fourths of the entire commercial stone production of the country. Limestone quarries are widely distributed, and almost all states have some production. Of the total tonnage produced, much is in the form of crushed stone for use in concrete, for agricultural use, and for fluxing purposes in blast furnaces. The amount used in agriculture as lime to overcome acidity in soils or as an ingredient in commercial fertilizer is increasing rapidly. The dimension stone produced is used almost entirely in construction (Fig. 330).

Indiana or Bedford limestone is the most widely used natural stone for dimension purposes in the United States. The quarries are located in southern Indiana, with Bloomington and Bedford as the principal centers (Fig. 331). Markets extend from the Atlantic seaboard to the vicinity of the Rocky

Figure 331.



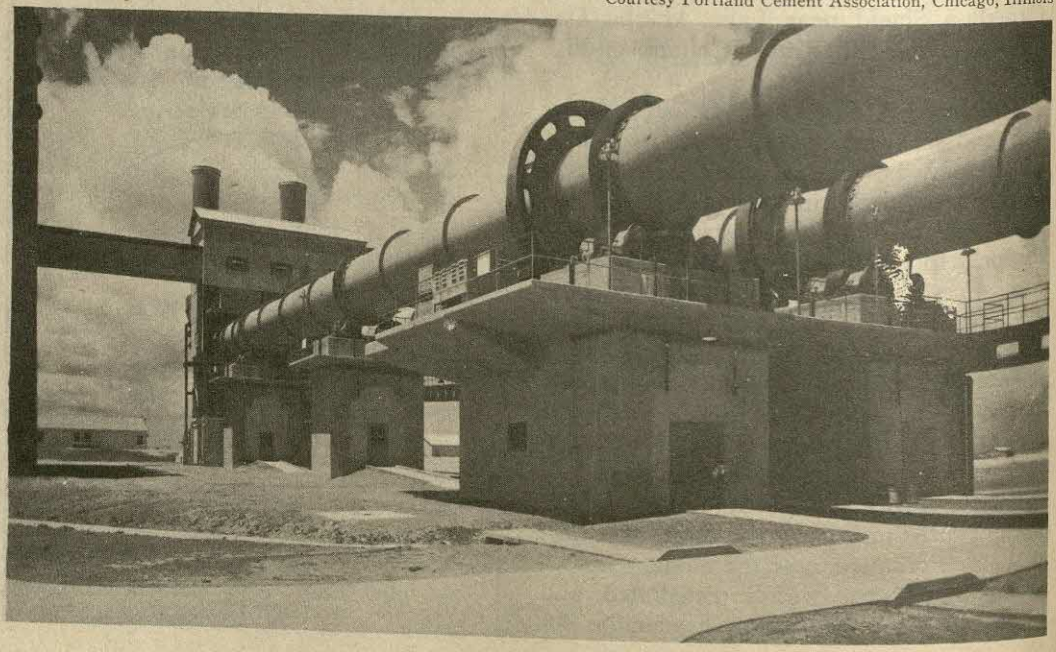
Mountains. Among the reasons for the popularity of Indiana limestone are its pleasing color, its uniform structure and appearance, the thick beds from which it may be quarried, the comparatively low cost of quarrying, and the ease of milling it into desired forms. However, the greater ease with which concrete can be poured into any desired form and the durability of foundations and walls thus made combine to reduce the demand for dimension limestone. As a result, the tendency is toward larger quarries, complete mechanization, and economy of operation.

THE CEMENT INDUSTRY. In early days cement was made by mixing slaked lime with volcanic tuff, which resulted in hardness and remarkable durability. Such cement was used by the Romans in building bridges, surfacing roads, and constructing aqueducts, and it is still being made near the volcanoes of Italy. It is known as *pozzolan cement*, after the town of Pozzuoli near Naples. Later it was learned that a cement similar to pozzolan could be made by heating some impure limestones to high temperatures. To this product the term *natural cement* was applied. This was used until near the close of the nineteenth century, after which *Portland cement* took the lead and now dominates the field. The term *cement* as currently used presumes Portland cement, unless specifically stated otherwise. The invention of Portland cement is credited to Joseph Aspdin of Leeds, England, who made cement by heating powdered limestone and clay and found that a mixture of the product with sand would harden under water, thus giving rise to an artificial stone that resembled a sandstone quarried on the Isle of Portland, England.

Although the manufacture of Portland cement developed rather slowly in the New World because other building materials were plentiful, rapid expansion took place after 1900, and it now ranks as one of the great industries of the United States. The total annual output of the country has grown

Fig. 332. Rotary kiln in cement plant. The kiln, about 400 feet long, is supported by giant roller bearings, and rotates at an average rate of three-fourths of a turn per minute. The kiln is inclined about three-quarters of an inch for each foot in length to facilitate continuous passage of the contained mixture.

Courtesy Portland Cement Association, Chicago, Illinois



to exceed 300 million "barrels" (weight 376 pounds each), with a value of over a billion dollars.

The manufacture of Portland cement involves many different operations, but the essential features are: (1) selection of raw materials that will provide the essential constituents—lime, silica, and alumina—in proper proportions; (2) grinding of the raw materials, usually limestone and clay or shale, to great fineness; (3) introduction of the powder in wet or dry form into a rotary kiln 300 feet or more long, where it is subjected to temperatures of 2,500° to 3,000°F.; and (4) grinding of the fused product of the kiln, which emerges as white hot balls about the size of marbles and known as clinkers, into a powder finer than flour. (See Fig. 332.)

During the final grinding process small quantities of gypsum are introduced because this mineral serves to retard the rate of "setting" or hardening of the cement. After this operation, which takes place in the "finishing mill," the cement is either passed to huge storage buildings called *silos* or is fed into sacks.

The number of plants in operation in the early 1960's was about 180, scattered over 39 states. Since the raw materials are heavy in proportion to value, cement manufacturing finds its most favorable location where limestone, clay, fuel, and markets are all in close proximity. Eastern Pennsylvania meets these conditions and has become a major center of cement manufacture in the United States. Fortunately, the heavy raw materials are widely and generously distributed, and some kind of heating medium—coal, petroleum, or natural gas—is usually available, so that all sections of the United States can be supplied with Portland cement without unduly long haulage and high expense.

The cement industry, largely an achievement of the present century, has attained the status of a great, world-wide industry, the activity of which is viewed as an index of industrial progress. At present the list of countries producing cement is very long, but Europe, including the Soviet Union, accounts for about half of world production, and the United States for a little less than one fifth (Fig. 333).

Cement deserves high rank as a factor in true conservation. Through it, crushed and broken rock which otherwise would be considered waste now far outranks dimension stone in value of output. It makes possible many types of permanent structures, such as large buildings, bridges, and road pavements, with a saving of timber, metallic, and other resources. Its importance is becoming so great that it has been said that the term "Steel Age" is a misnomer for the period in which we live and that it should be called the "Steel and Concrete Age."

MINERALS OF IMPORTANCE TO THE CHEMICAL INDUSTRIES

Salt. Salt (halite, NaCl) is the only mineral which enters directly into the diet of man and beast on a large scale and which is indispensable to their existence. Primitive people showed great ingenuity in their means of securing supplies, and among some people salt even took the place of money. Places where salt could be obtained were declared neutral ground by Indian tribes

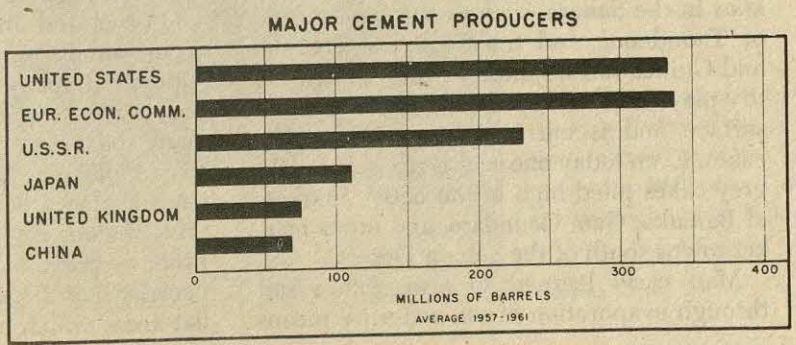
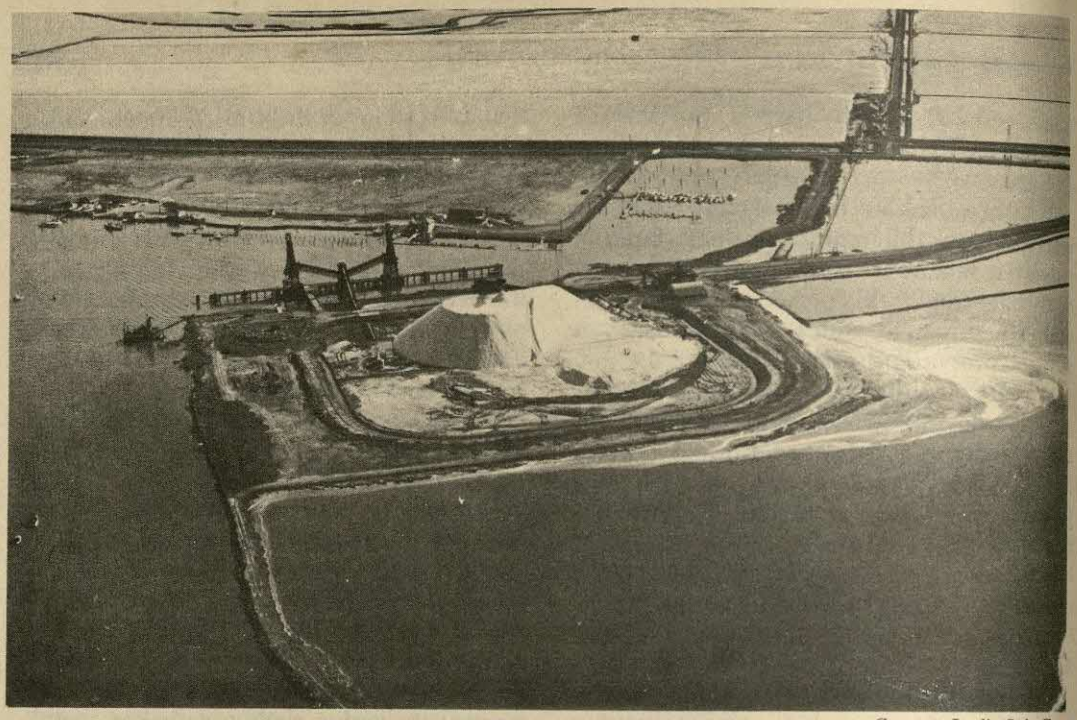


Figure 333.



Courtesy Leslie Salt Co.

Fig. 334. Solar salt ponds, San Francisco Bay area. Salt is precipitated from bay water by sunshine evaporation. Note the large pile of salt ready for shipping. Much of this salt is used for industrial purposes.

of the Great Plains. Tribes otherwise hostile would meet at such places and gather their salt in friendly rivalry, whereas meeting elsewhere might lead to deadly combat. This practice was a direct tribute to the necessity of salt in man's diet.

In the humid tropics, where soil leaching is paramount, salt is difficult to come by locally, and the diet is apt to be deficient in salt. In such areas there may be a real "salt hunger," and the inhabitants must obtain salt from elsewhere, even if the price may be high. Thus for centuries there has flourished a remunerative trade in salt between certain salt-producing *playas* or *sebkhas* in the Sahara, such as the famous one of Taoudenni, and the Sudanese savanna and Guinea forest lands to the south. In the dry playas the salt occurs in layers near the surface and is cut into larger or smaller cakes. Even today one can see these whitish-grey cakes piled high in the native markets of Bamako, Gao, Goundam, and other market towns south of the Sahara Desert.

Man early learned to also obtain salt through evaporation of sea water by means of solar heat in enclosed basins at the shore. Much salt in the world is still produced in this manner, usually in areas of warm, sunny, and dry climate, or where there is at least a long, dry season, as for example, in the extremely dry, sunny Red Sea region, in the Mediterranean region, and along the coast of southern China. Even in the United States some salt is produced in this manner. A considerable number of salt pans ("salt ponds") are located along the shores of San Francisco Bay, especially in its southern portion. In 1960 solar salt still accounted for about 5 per cent of total United States production (Figs. 334, 335).

On the land and in small quantities, salt occurs almost universally. It is a minor constituent of many clays, shales, and sands, and it is also present to a slight extent in many soils. It exists in the cavities and pore spaces of some rocks and thus may give rise to salt-water springs and salt wells. In arid regions, particularly where interior drainage prevails, many kinds of salt, but especially halite, become concentrated in low, flat areas which are the termination of one

or several intermittent streams, the playas and sebkhas mentioned above. Through evaporation the salt is precipitated here in layers of varying thickness, which can then be quarried. Most of the salt of the world, however, comes from thick underground strata of salt or masses of salt in *salt domes.** The formation of this salt dates back to previous geologic periods (Fig. 336).

Pure halite in perfect cubical crystals is colorless, but the salt as it occurs in most deposits usually is not pure, varies in color from whitish to grey, and is referred to as *rock salt*. The crystals are irregular, sometimes small and sometimes fairly large. Deposits of rock salt are exploited in many countries. Methods of winning the salt vary from underground mining of the solid beds to obtaining it by solution methods, that is, by pumping hot water down to the bed of rock salt, churning it about by specially devised agitating methods, and then pumping up the brine. (See also Fig. 340.)

USES OF SALT. Not so many years ago salt was used chiefly for domestic purposes, and that use still provides the principal demand in most of the nonindustrial countries of the world. However, the recent expansion of the chemical industries in Europe, the United States, the USSR, Japan, and elsewhere has led to increased demand because salt has been found to be an indispensable raw material for the manufacture of a great number of chemicals. In recent years the

* See the section on potash in this chapter.

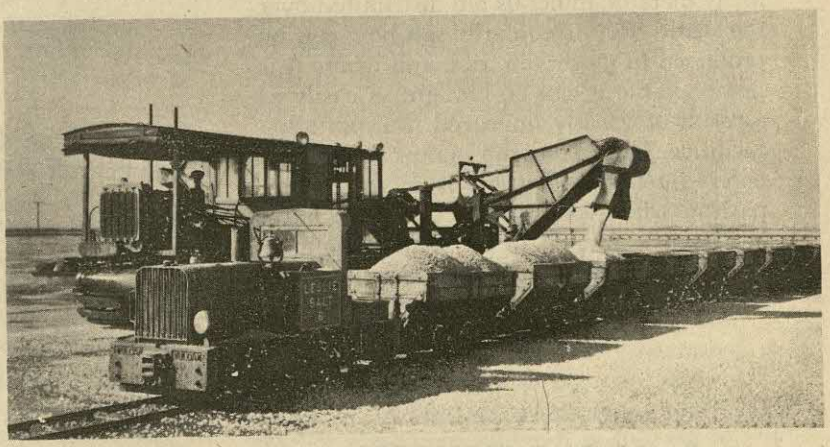


Fig. 335. "Harvesting" of salt in one of the salt ponds illustrated in the previous photograph.

Courtesy Leslie Salt Co.

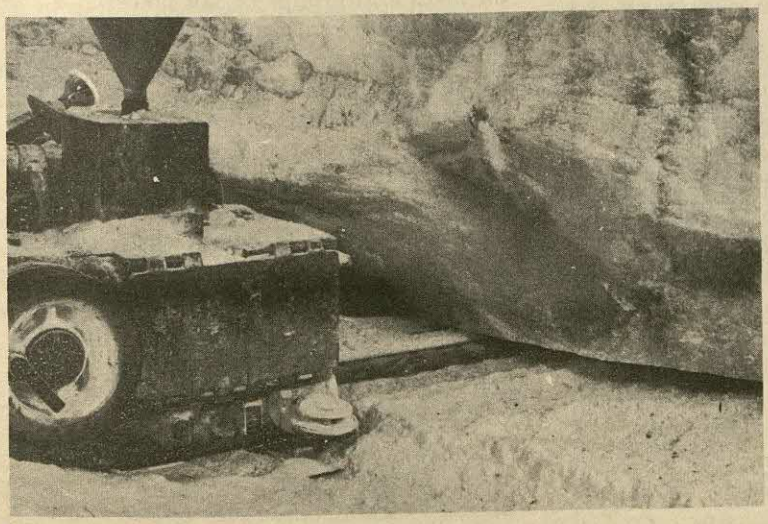


Fig. 336. In an underground salt mine. Undercutting operation in salt stratum. Salt everywhere. Wall of rock salt, powdered salt underfoot. Morton mine, Grand Saline, Texas.

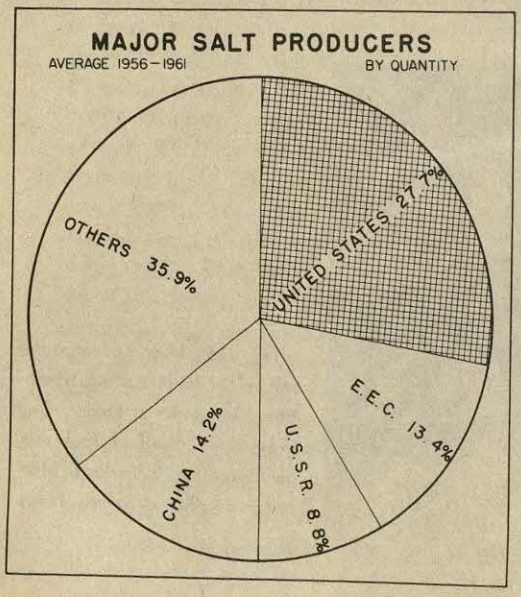
Courtesy Morton Salt Co.

chemical industries have used about two thirds of all the salt produced in the United States, its major importance being its use in the manufacture of various bleaches, soda ash, dyes, soaps, and numerous other products.

Other special uses are for livestock, for water treatment, and for preservation purposes. Still another use is for control of dust and ice on highways and railways, a use that in some years requires quantities exceeding the total amount purchased by the meat-packing and fish-curing industries combined.

GEOGRAPHIC DISTRIBUTION OF SALT RESOURCES. Although in parts of the world salt once was so scarce that it brought very high prices, at present it is a common, low-priced commodity. While, as we have seen, many metallic minerals are distributed over the world very irregularly, salt now can be produced in most countries, and where it is not available it can be brought in easily as a result of greatly improved transportation facilities. Thus today the amount of salt that enters international trade is small in comparison with world production. The latter has been estimated to be in the neighborhood of 100 million short tons in recent years (Fig. 337).

Figure 337.



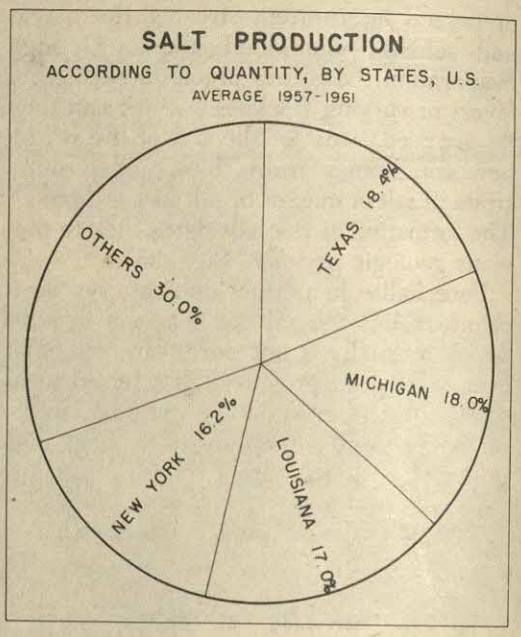


Figure 338.

SALT IN THE UNITED STATES. The United States has large resources of salt. Some of these are in the form of rock-salt strata in sedimentary rocks, as in the New York-Pennsylvania-Ohio-Michigan area and in the great underground salt basin that extends from western Texas to central Kansas. Other occurrences are in the form of salt domes, as in southern United States, or in the form of brines, as in the Illinois basin. In western United States there are many salt lakes and groups of salt lakes.

Owing to the great expansion of the chemical-manufacturing industries of this country, the production of salt in the United States has more than tripled since the late 1920's and is now over 25 million short tons. The leading states are Louisiana, Texas, Michigan, New York, and Ohio (Fig. 338).

Sulfur. Sulfur is widely distributed in igneous rocks, particularly lavas, but it usually occurs in such small quantities and in such association with other minerals that economic extraction is difficult and expensive. The sulfur used in industry is derived from three principal sources: (1) from *native sulfur*, which is exploited where found in fairly large bodies that are readily accessible; (2) from sulfide ores (*pyrites* in gen-

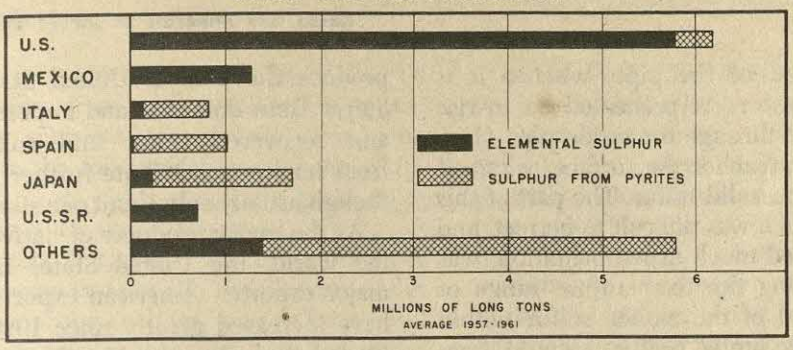


Figure 339.

eral), among which the principal one is *iron pyrite* (FeS_2); and (3) as "recovered sulfur," at oil refineries and gas-processing plants.

For many purposes native sulfur is preferred to the pyrites because it can more readily be converted into desired combinations and because there is no problem of disposal of waste, since native sulfur is so nearly pure that no waste products result from its utilization. In iron pyrite sulfur is the valuable element, not iron, and what remains after the manufacturing process becomes waste because no satisfactory method of rendering the iron completely free of sulfur has yet been developed. Sizeable quantities of sulfur are produced commercially in the form of by-product sulfuric acid from sulfide ores, such as those of copper, zinc, and lead, in nearly all countries where mining and smelting of these ores is carried on. The widespread distribution of these ores as well as of iron pyrites makes world depletion of sulfur reserves virtually impossible. The countries that rank high in pyrite-sulfur production are Norway, Japan, Spain, Cyprus, Italy, West Germany, and East Germany.

While native sulfur is produced by mining in over a dozen countries, and particularly in Japan, Italy, and the USSR, most of the world's output of native sulfur is now supplied by the Gulf coast of Texas, Louisiana, and Mexico, as so-called Frasch sulfur (Figs. 339, 340).

Total world production of sulfur consists of approximately 6 to 7 million long tons of Frasch sulfur from the United States and Mexico; 0.8 to 0.9 million long tons of sulfur mined; 1 to 3 million long tons of "recovered" sulfur; and from 0.1 to 0.2 million long tons recovered from sulfide ores. Finally, usually almost 8 million long tons are obtained from pyrites. In Europe and Japan they are the principal source of sulfur.

USES OF SULFUR. The most significant use of sulfur is for the manufacture of sulfuric acid, a leading raw material for the chemical industries. In addition, sulfur is essential in the manufacture of fertilizers, paper and pulp, and for a number of minor purposes. In the United States about four fifths of the production of sulfur is made into sulfuric acid.

SULFUR IN THE UNITED STATES. The production of native sulfur in the United States ordinarily exceeds 5 million tons per year, more than 98 per cent of which is represented by the output of companies operating in the Gulf coast deposits of Texas and Louisiana. Prior to the turn of the century, sulfur was discovered in the cap rock of salt domes in the Gulf coast area, but because of the unconsolidated sediments beneath which it was found, mining by the shaft method proved impracticable, and exploitation was delayed because of lack of means of getting at the sulfur. This handicap was overcome by Dr. Frasch, a chemist formerly associated with the petroleum industry, who devised the method named after him, whereby the sulfur could be melted and forced out of wells by water pressure. The method involves sinking, by means of drilling a triple pipe system, a large pipe outside with smaller ones inside through the unconsolidated strata into the sulfur-containing cap rock, usually limestone. The sulfur is melted by injecting superheated water through the outside pipe. Then the molten sulfur, which is heavier than water, flows into a small pit known as a *sump*, at

the lower end of the pipe, whence it is forced by pressure of preheated air to rise in liquid form through the inside pipe (Fig. 340). Thus it reaches the surface, where it cools into pure, solid sulfur. The part of this operation which was difficult to perfect, and which required much experimentation, was that of keeping the temperature range of the water and of the molten sulfur within rather narrow limits. Sulfur melts at temperatures varying from 238°F. to 240°F. and in that form is a thin, light-yellow liquid. If heated too much it becomes so viscous that it cannot be forced out by water pressure. To retain a fairly narrow temperature range through a pipe system that in many cases extends down more than a thousand feet demands a high degree of control of heating and cooling; however, when such control became possible this method of obtaining sulfur proved to be very economical.

Because of the low cost of production from salt domes which contain sulfur, domes located in the Gulf Coastal Plain from the New Orleans area to the Rio Grande, now produce the bulk of United States sulfur. Sulfur from domestic and imported pyrites and recovered sulfur and sulfuric acid from smelters contribute further quantities, though usually only about one sixth as much.

As the major producer of native sulfur in the world, the United States is also the major exporter. American exports of sulfur have increased greatly since 1920, and the United States now ordinarily exports from one fourth to one third of its output. The leading markets are in Europe, especially the United Kingdom, West Germany, France, and the Netherlands, and in Canada, Australia, New Zealand, Brazil, and India.

MEXICO. Most of the Mexican production is from salt domes in the eastern coastal plain, which is the continuation of the Gulf Coastal Plain of the United States.

COMMERCIAL MINERAL FERTILIZERS

Nitrates, phosphates, and potash are the chief ingredients of most of the various mixtures referred to as commercial mineral fer-

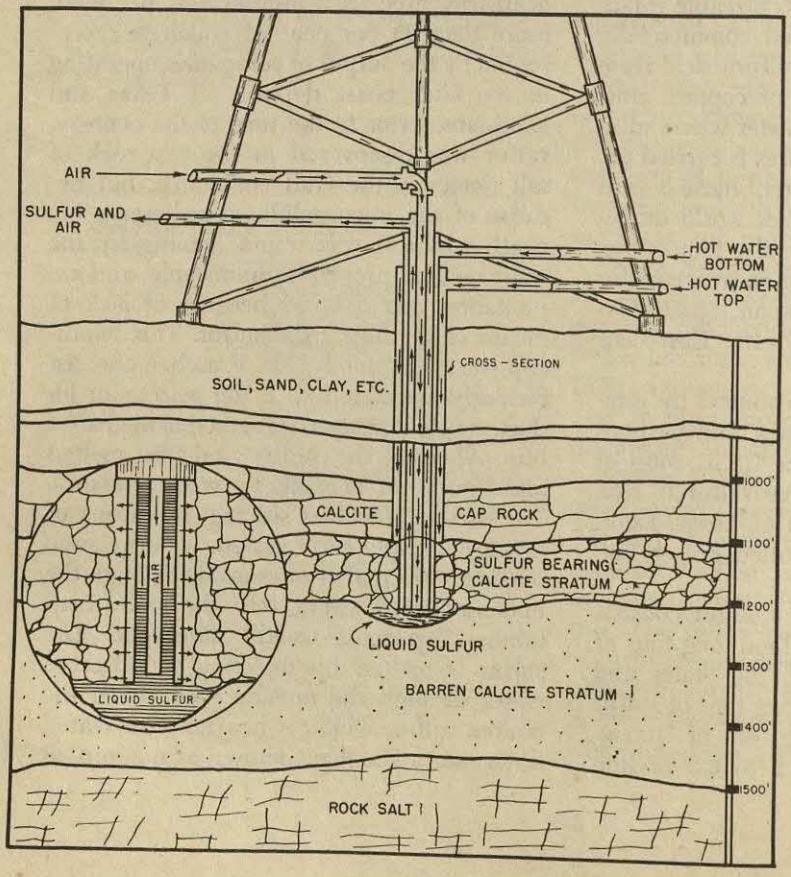


Fig. 340. The essential features of the Frasch method of mining sulphur. Note carefully the concentric arrangement of pipes and the purpose served by each. The inset drawing at lower left is the bottom hole enlarged to give details. It should be added that the molten, liquid sulphur is forced up and out by air and steam pressure indicated by lower vent at left side of derrick.

tilizers. In many regions of the world the application of mineral fertilizers is necessary for successful agriculture. It may be said that the following five methods of increasing crop yields constitute great milestones in agricultural progress: (1) the introduction of clovers and other legumes into the crop system; (2) the plowing under of green crops such as peas, clovers and other legumes, all broadly included under the general term of *green manures;* (3) the utilization of root crops, such as mangels, turnips, and beets, thereby breaking up the practice of continued grain farming on the same plot of ground and at the same time improving the physical condition of the soil; (4) the scientific breeding of better crop plants and domestic animals; and (5) the scientific application of mineral fertilizers. In many agricultural regions the latter practice has become general as a result of the chemical study of soils, first undertaken seriously about the middle of the last century in Europe.

In many countries productivity of the soil has been greatly increased during the last hundred years or so by the various methods mentioned, singly or in combination, but especially by the careful use of mineral fertilizers. England now averages about 30 bushels of wheat per acre. Denmark, southern Scandinavia, and the adjacent lowlands of Germany and the Netherlands produce average yields of 30 to 40 bushels per acre, although the land has been tilled for centuries. The specter of want has been routed, at least temporarily, and the world gives promise not only of greater production per unit of area but also of a production of tillage crops on the same field more prolonged than seemed possible to students of earlier times.

In Europe the consumption of commercial fertilizer reaches its highest point in the Netherlands, Denmark, West and East Germany, southern Sweden and Norway, eastern England, and northeastern France. All these comprise an area where yields per acre are highest, and this is to a great extent a response to heavy applications of fertilizers usually in combination with barnyard manures.

In the United States the fertilizer industry has become a large industry and one of growing importance to the success of agriculture. The output of American fertilizer plants has increased from less than 3 million tons in 1899 to over 10 million tons at present. With respect to both production and consumption, the industry is well developed in the eastern part of the country, throughout the states from New England to Florida, although in the aggregate the heaviest use of fertilizers is in the Southeast. There rainfall is heaviest, temperatures are relatively high, soils, often light, have been leached the most, and fertilizer is most needed. In recent years, however, the use of fertilizers has increased in the Pacific coast states and also in the states between the Appalachians and the Rocky Mountains (Fig. 341).

Fertilizers may be applied separately, and some farmers prefer to purchase the several ingredients and to prepare mixtures in accord with the needs of the particular fields to be tilled and the crops to be grown. Others prefer to buy ready-mixed fertilizers prepared according to formulas worked out by farmers and pedologists to fit the general needs of soils in particular districts. The mixed fertilizers are usually designated by numerical symbols which refer to the three essential ingredients, namely, nitrates, phosphates, and potash. Thus, "3-8-4" is a fertilizer which has a plant food content of 3 pounds of nitrates, 8 of phosphates, and 4 of potash in each 100 pounds of the fertilizer as purchased. The remaining 85 pounds consist of carriers, materials which have a beneficial effect on the soil. Some form of lime is ordinarily the chief constituent.

Nitrates. Nitrogen is the most expensive of the fertilizer materials. It is the chief constituent of the air, the supply in nature being inexhaustible, but it may be obtained indirectly from other sources as well. Indirect sources of nitrogen include, for example, dried blood and tankage from packing plants, fish scraps, dried crabs, and other fish refuse. The direct use of fish as fertilizer is still practiced in parts of the world where fish are plentiful and land is scarce. It is claimed that the Indians showed the first settlers of Plymouth, Massachusetts,

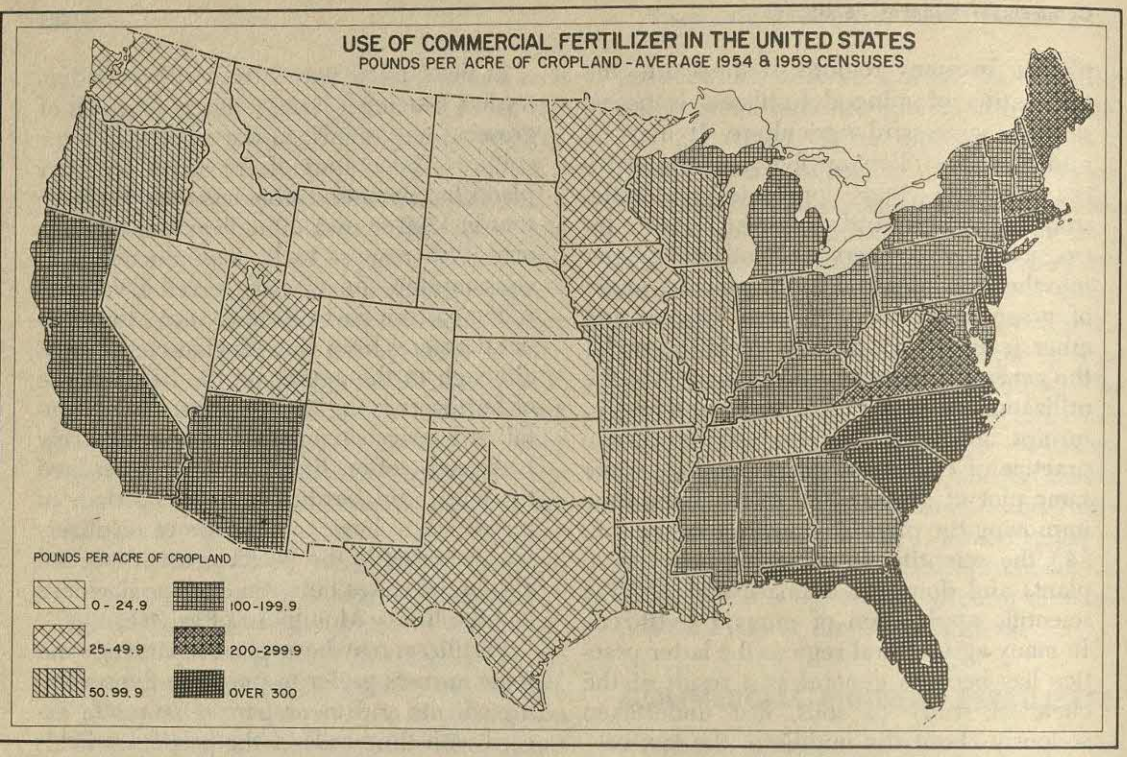


Figure 341.

how to produce Indian corn by placing a fish with every hill of seed. Nitrogen can also be extracted from the air, or from other sources, and converted into a form fit for plant food or industrial purposes. This, of course, involves heavy investment in plant and equipment and also rather heavy expenses for power.

Commercial fertilizers make use of nitrate obtained through fixation from the air or by means of other chemical processes, or of nitrates obtained from desert areas where the mineral nitrate has accumulated as a result of evaporation of waters under arid conditions. Mineral nitrate is a product of the extreme desert. Although small quantities have been produced in Death Valley, California, and in some other desert areas, from a commercial point of view Chile has long been the world's only important source of supply. The practically rainless coastal desert of northern Chile, located between the lofty Andes ranges and the Pacific coast, was found to contain the world's greatest store of mineral nitrates. These deposits of highly soluble nitrate of soda were slowly concentrated there through the ages, and man's exploitation is likely to be a harvest of short duration in comparison with the period that was needed for their accumulation. The mining methods are simple. The cover of a few feet of non-nitrogen-bearing materials is removed by steam shovels, and below it is found the relatively soft nitrate ore, known as *caliche*. This is loaded by steam shovels into cars and hauled to the refining plants, where the nitrate is dissolved by hot water, thus separating it from the insoluble, earthy material. The solution is then evaporated and the nitrate precipitated.

THE DEVELOPMENT OF THE CHILEAN NITRATE INDUSTRY. Commercial exploitation of the Chilean deposits began in 1830, but not until the late 1870's was large production attained. The deposits then had been developed largely by Chileans, although the nitrate fields were located in desert lands belonging to Peru and Bolivia. The war of 1879-82, by Peru and Bolivia against Chile, ended in victory for the latter; as a result, Chile became master of the world's greatest

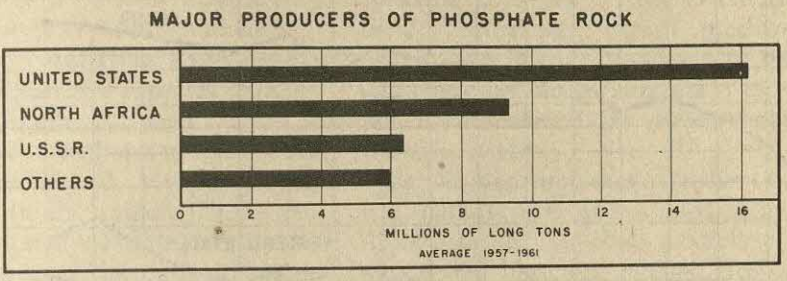


Figure 342.

nitrate deposits, receiving what proved to be a colossal indemnity.

The nitrate industry transformed a barren desert into an area of industrial activity. It stimulated the growth of coastal towns and railroad facilities and through export taxes contributed much to the nation's income. However, the percentage of the world's nitrogen provided by Chile has steadily declined, from a peak of 85 per cent in 1885, and now amounts to only a small percentage. Also, the actual exports have tended to decline. The United States has continued to take about 40 per cent of the Chilean output. Despite the expansion of synthetic nitrogen production it seems probable that imports from Chile will continue because of low-cost ocean transportation.

The bulk of the world's nitrogen fertilizers is now made synthetically. This industry is discussed briefly in the next chapter, as a subdivision of the chemical industries.

Phosphates. Rock phosphates are chiefly phosphates of lime, and, while their value as fertilizers depends on their phosphorus content, most soils that need phosphorus also need lime. Phosphates also constitute the raw material for a number of products of the chemical industries. The United States has consistently been the principal producer of phosphates during the present century. The countries of northern Africa, Morocco, Tunisia, Algeria, and Egypt, taken collectively, constitute the major competitive region outside the United States (Fig. 342). Aside from the United States and North Africa, other fairly important producers are a few islands in the South Pacific, particularly Nauru, northeast of the Solomon Islands. There is a host of minor producers.

PHOSPHATE ROCK IN THE UNITED STATES. While phosphate rock is known to exist in a number of states, commercial production is limited to relatively few. Florida holds undisputed supremacy in the output of phosphate rock, with Tennessee in second place. The western states, Idaho, Montana, Utah, and Wyoming, produced only small quantities before 1935, but since that time their production has continued to expand, so that at present their combined production well exceeds that of Tennessee (Fig. 343).

Phosphate production in Florida is favored by the low cost of mining, large reserves, nearness to domestic markets, and ocean transportation to foreign markets. Much of the rock phosphate occurs as an unconsolidated, thick layer made up of particles of an average diameter of half an inch. This phosphate, therefore, is known as "land pebble phosphate." The overburden is readily removable by steam shovel. The land pebble layer is so friable as to make low-cost mining possible (Figs. 344 and 345). Land pebble accounts for the bulk of Florida's production, which is found in Polk and Hillsborough counties, south and southwest of Lakeland. Some phosphate is known as "hard-rock" phosphate and occurs associated with clays and other materials farther north in Florida in a belt that parallels the Gulf coast. Conditions of exploitation are not as easy as they are for land pebble, and thus at present production from this type of deposit amounts to less than 1 per cent of the Florida total.

Deposits in western United States are large, but they occur in bedrock (shales) which have been folded and faulted, so that in most places underground mining is necessary. The reserves of phosphate rock that

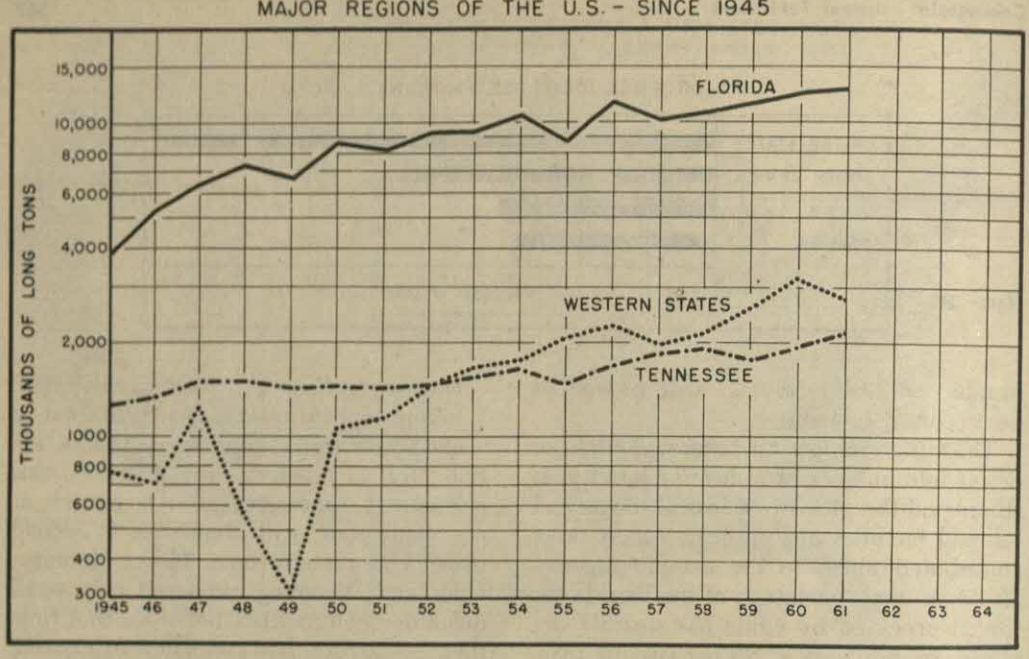


Figure 343.

Fig. 344. Mining phosphate-bearing material by means of a dragline in Polk County, Florida.

Courtesy American Agricultural Chemical Company



have been mapped in the area from northeastern Utah through Wyoming and eastern Idaho to the Butte and Helena sections of Montana give assurance of supplies of phosphate for many decades to come.

Consumption of phosphates in the United States has increased steadily, especially since the late 1930's. In the middle 1930's the apparent consumption was less than 3 million long tons, but in the early 1960's it reached over 13 million long tons.

Large quantities of phosphate rock are exported by the United States every year. During the five-year period ending in 1939, the average annual exports slightly exceeded one million long tons; in the early 1960's total exports reached over four million long tons. Europe consistently has been the most important customer. Other major customers are Canada and also Japan, which requires much fertilizer to maintain the high crop yields that are necessary to help support its dense population. Exports to Europe must meet the competition of the large quantities of phosphates exported from Morocco, Tunisia, Algeria, Egypt, and, recently, Senegal.

Potash. The term potash is applied to potassium oxide (K_2O), in which the element kalium (or potassium in English-speaking countries) is the essential ingredient. Statistically, potash production is usually expressed, irrespective of the form and degree of purity, in terms of equivalent potassium oxide (K_2O), a compound never found in nature.

Potash is an important ingredient in chemical manufactures and is used in many industrial products such as medicines, paints, paper, and bleaching agents. However, its greatest use is in agriculture, especially in Europe and in the New World, where it is indispensable if high yields are to be obtained. Justus von Liebig, a prominent German chemist, discovered in 1850 that potash compounds constitute essential plant foods in the soil which are not readily replenished by nature. Since continued cropping leads to serious depletion of available potash, this causes crop yields to decline. The same scientist discovered also that productivity may be restored or increased by the application of potash and other fertilizers in suitable proportions. The discoveries of von Liebig and some of the rules he established are generally credited with marking the introduction of the scientific use of mineral fertilizers into agricultural practices.

Sea water contains not only ordinary salt



Fig. 345. Plant for washing phosphate rock, and for recovering the phosphate. The treatment of the phosphate rock requires much larger investment than the mining.

Courtesy American Agricultural Chemical Company

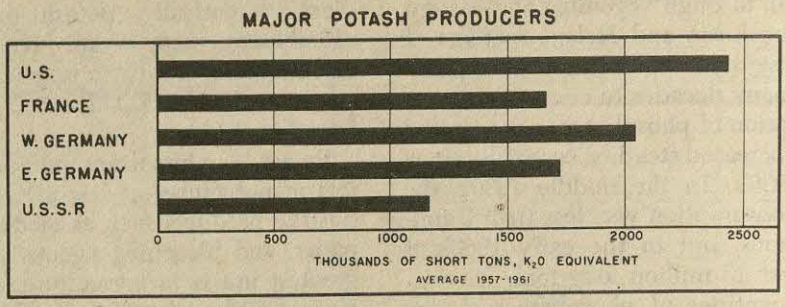


Figure 346.

(halite, NaCl), but also many other types of salt, in several of which potash (K) may be one of the constituents. It does not pay to reclaim potassium from ordinary salt water, but it does where, through constant evaporation, the water has become so salty that it is a brine. This is the case, for example, in the Dead Sea, where potash is produced from a closed-off portion of this lake. Another example is Searles Lake, a playa in the Mojave Desert of California. From the briny water pumped up by shallow wells many useful substances are manufactured, among them potash. In the geologic past climatic conditions have occurred in certain parts of the world which caused large-scale evaporation of sea water from extensive shallow seas. Long-continued evaporation resulted in the deposition of thick layers of gypsum and various salts, which later were covered by clays and hundreds or thousands of feet of other deposits that eventually hardened into rocks of various kinds, thus protecting the salt strata underneath. Today some of these strata still lie nearly horizontal, but in many places they were folded subsequent to deposition. Elsewhere again masses of salt have collected from such strata deep underground and slowly worked their way upward through the overlying rocks, bending these rocks up along their edges. These are the so-called salt domes. Many domes never reached the surface, but some did, for example, the "salt mountain" near Djelfa in Algeria. From the air this mountain makes a most peculiar impression. The salt exposed is rock salt (halite) of a dirty grey color, but the little valleys that have been eroded in it, and where salt has been redeposited, are brilliantly white. The mountain has been able to survive in part only because of the very dry climate of the area.

Domes of this type are usually more or less circular in shape, may range in diameter from less than one to five or even seven miles, and in many cases do not reach the surface. Where covered by other bedrock the top is usually somewhat rounded, with a "cap" of gypsum or anhydrite, which sometimes contains sulfur, as mentioned previously. The salt mass may extend downward for three to five miles. As mentioned before, the sedimentary rocks through which the plug of salt has pushed its way have usually been pulled up with the movement, and near the plug they may dip at quite steep angles. Such strata sometimes have become traps for oil (see Fig. 263).

In some areas there are among such salt domes a number that contain potash salts, and where, in this manner, potash salts are brought within exploitable distance from the surface. This is the case, for example, in the North German Plain and in Russia north of the Caspian Sea. Elsewhere potash salts occur in more or less regular beds, as in the American Texas-New Mexico salt basin. Among the many salts of this type the most important are sylvite, polyhalite, and carnallite, of which the first is by far the richest in potassium oxide.

Commercial potash is a product that must be processed to a greater or lesser degree from the original salts because of the presence of impurities. The two principal uses of potash are: (1) for fertilizer, the potash thus used being referred to as *agricultural*

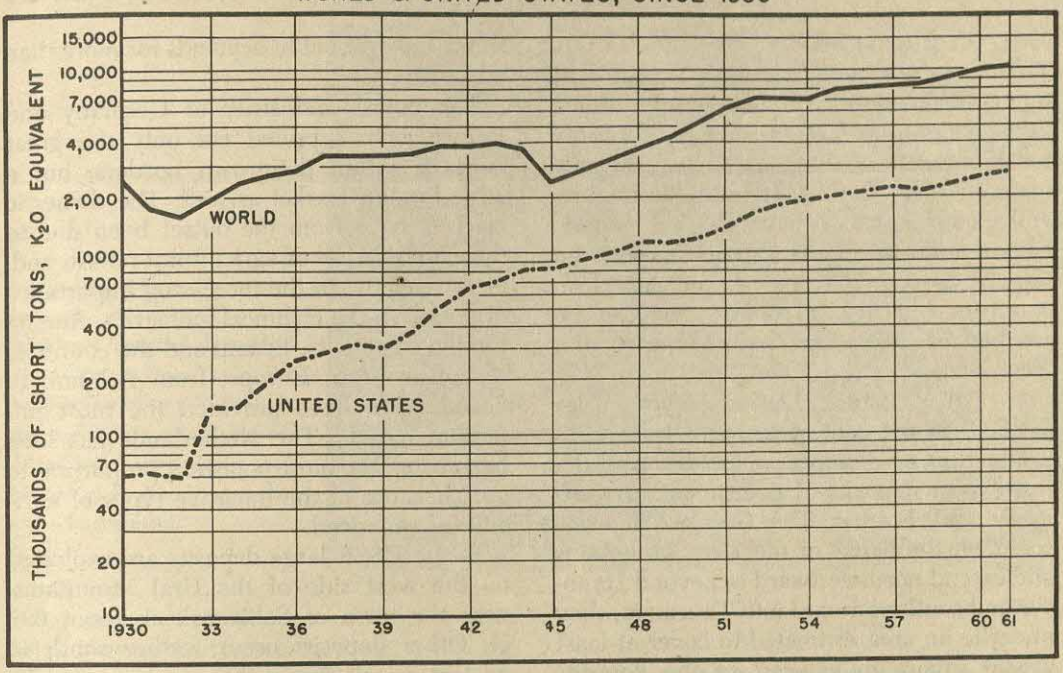


Figure 347.

potash; and (2) for use in the chemical industries, where a high degree of purity is necessary, the potash being known as *chemical potash.*

WORLD PRODUCTION OF POTASH. The number of countries that produce potash is comparatively small, and among these there are five major producers: the United States, West Germany, East Germany, France, and Russia (Fig. 346).

POTASH IN THE UNITED STATES. Prior to World War I, the United States was almost completely dependent upon Germany and France for its potash supplies. When war conditions cut off these sources, the scarcity of supplies led to record-breaking prices and the development of domestic sources. Some of the alkali lakes in the western part of the Sand Hills Region of Nebraska, which were known to contain potash salts, attracted attention. Commercial production began in 1915, and by 1918 Nebraska had become the major domestic producer of the much-needed potash. However, since the brines had to be evaporated by means of expensive fuel and machinery, production costs were high. When the war was over, competition of European potash could not be met, and this suddenly ended the potash dreams of the ranchmen.

Searles Lake, California, also came into potash production during World War I, but because of the accessory minerals found in its brines it proved able to continue production under normal peacetime conditions.

The output of marketable potassium salts in the United States has increased steadily from less than 400,000 short tons prior to 1930 to over three million in the early 1960's. The Carlsbad field of New Mexico is the scene of the most extensive mining operations and provides by far the major part of the production. Since 1941 annual production and apparent consumption of potash in the United States have been nearly equal (Figs. 347, 348, 349).

Extensive beds of potash salts have been found not only near Carlsbad but in much of this portion of southeastern New Mexico and with extensions into Texas. Other extensive potash-bearing formations have been found to occur under somewhat less favor-

able conditions in Wyoming and Utah. These reserves seem to make it certain that the United States will not again become dependent upon foreign sources of supply for this vital fertilizer and chemical raw material. The United States both imports and exports potash materials, but exports have tended to exceed imports. Exports go largely to Canada and Latin American countries but also to others that can be reached easily by sea, such as Japan and New Zealand.

POTASH IN EUROPE. During the years prior to 1930, 90 per cent or more of the world's production of commercial potash was derived from deposits of potash salts in Germany and France. The German deposits occur on the flanks of the Harz Mountains and extend northwestward to beyond Hanover and southwestward into Thuringia; they underlie an area estimated to cover at least 25,000 square miles. Part of the deposits occurs in more or less flat-lying beds, part comes within exploitable distance in salt domes. The French deposits lie in the upper Rhine Valley near Mulhouse, where the producing area has been estimated to include about 70 square miles. Estimates of the German potash reserves vary widely, but even the most conservative figures give assurance that at the present rate of consumption they will suffice to meet the potash demands for a thousand years or more. The deposits in France are estimated to be great enough to supply any probable demands for more than a century.

The potash industries of Germany and France have supplied not only the great markets within their own borders, but a large foreign market as well. The domestic markets have from the outset been due to the extensive use of agricultural potash and, more recently, to the increasing importance of potash in the chemical industries. Among foreign customers, Britain and the countries of northwestern Europe, from Belgium to Scandinavia, have provided the most important outlets. The Netherlands has long been using the most potash in proportion to area because of the intensive types of agriculture practiced.

In the USSR large deposits are exploited on the west side of the Ural Mountains, near the town of Solikamsk at about 60° N. Other deposits occur farther south in an area of salt domes that reaches from the northern part of the Caspian Sea to beyond Uralsk and Orenburg (formerly Chkalov).

Thus since World War I the international potash picture has changed greatly, and largely because of developments in the Soviet Union and the United States. These two countries have ceased to be important markets for French and German potash and are now capable of surplus production for international trade. The change was accelerated by the tendency of the European producers to organize cartels; prices were

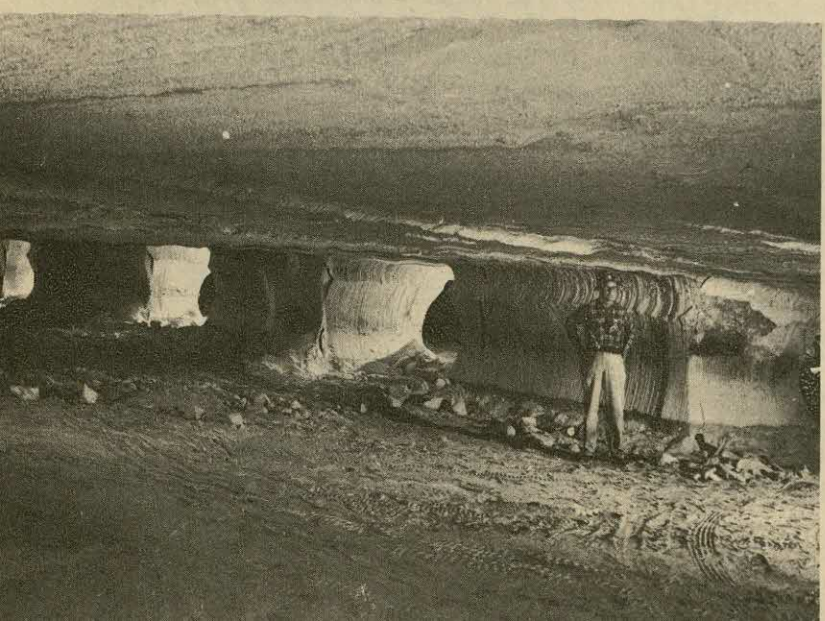


Fig. 348. Underground view of the same mine as following photograph, showing mined area in potash stratum. The "long wall" mining system is practised, which leaves only 8 to 10% of the potash for support purposes. The striations are caused by the huge rotary or "bore type" mining machines that are used.

Courtesy U.S. Borax Co.



Fig. 349. Above-ground portion of underground potash mine near Carlsbad, New Mexico. There are three shafts. The head frame of one is visible in the middle ground, to the left of the little smoke plume; spoil heaps and semi-arid vegetation in the background.

Courtesy U.S. Borax Co.

agreed upon and markets divided among the producers so as to make possible sales at abnormally high figures. This practice induced other countries to seek deposits within their own borders and to experiment with new production and refining methods in order to promote domestic production for the protection of their own national interests.

OUTLOOK FOR THE WORLD'S POTASH INDUSTRY. With rapidly increasing world population the need for more food and larger crop yields is becoming ever more pressing. Potash is a very important item in fertilizers, and manufacture of potash from sources other than the natural mineral salts is expensive. World demand for potash can be expected to continue to increase. Unfortunately, in the salt deposits of the world usable potassium salts are not by any means as frequent in occurrence or as plentiful as other salts, such as halite (kitchen salt). Still, presently known reserves appear to be quite large, particularly those of Germany, divided between West Germany and East Germany, the United States, and the Soviet Union. Spain, Poland, and Italy are some comparatively recent producers, though their production is still small. It seems quite likely that under the spur of gradually increasing demand new deposits may be discovered in other parts of the world.

PRESENT AND FUTURE ROLE OF THE MINERALS AND ROCKS OF DIRECT ECONOMIC IMPORTANCE

None of the minerals and rocks in this group rank with those whose names frequently appear in newspapers and financial journals, such as petroleum, natural gas, coal, or uranium, but nevertheless it is clear from the above discussions that a number of them play very important roles in any modern type of economy, and some even in more primitive economies. One reason why they do not attract so much attention is, perhaps, the fact that many of them are widely distributed geographically. In other words, there are many "have" countries and few, if any, "have nots." This is true for such materials as sand, gravel, ordinary clays, rocks such as sandstone and limestone, and minerals such as gypsum and salt. Of course, there are exceptions, such as potash, phosphates, and asbestos.

In general, however, the reserves and supplies appear to be quite satisfactory, even though it can be expected that the role played by a number of these rocks and minerals is likely to increase in importance. For example, with wood becoming more expensive as a result of continuing depletion of the cheapest kinds of stands of timber—the

natural stands—the use of other construction materials will increase. In the United States brick, cinder block, and concrete structures are more and more taking the place of the older-type "frame" (wooden) structures. Also, the chemical industries are still growing in importance.

In the case of fertilizers the outlook is not quite so rosy. Increased production per acre is becoming more and more of a necessity all over the world. This is going to require tremendous quantities of mineral fertilizers. Fortunately, we have learned to abstract nitrogen from the air. Potash and phosphates, though major deposits are known and exploited at the present time, and further discoveries are not excluded, may well cause serious problems in the future.

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28

Nature and Geographic Distribution of Major Manufacturing Industries

In the preceding chapters the discussion has centered upon natural resources, especially agricultural, timber, and mineral resources, as the basis of industrial development. A number of manufacturing industries were discussed briefly in the chapters dealing with the major raw materials upon which they are based, such as the meat-packing and dairy industries, pulp and paper industries, petroleum refining, the generation of electricity from water power, and the manufacture of steel, aluminum, and copper. Within the scope of a book dealing with the fundamentals of economic geography it is, of course, not possible to treat extensively the geographic aspects and geographic distribution of all existing types of industry. Because of their importance as constituent industries in many industrial districts and industrial regions, a number of other industries are treated briefly in this chapter, though only by major industry groups.

The following groups of manufacturing industries are discussed in the pages that follow: chemicals, textiles and related wearing apparel, rubber products, leather goods, machinery, transportation equipment, and electrical and electronic machinery and equipment.

In the discussions emphasis is upon the raw materials used and the finished goods and services resulting from manufacture, rather than on manufacturing processes. An appreciation of the economic significance of the latter would require rather detailed technical analyses which are far beyond the scope of this book. However, on the basis of previous chapters it is frequently possible to point out some of the geographic factors that enter into the problem of industrial localization and into an evaluation of the economic role of the products.

Classified as *manufacturing industries* are all those activities by which raw materials, partly finished materials, or potential components are converted into a more usable nature or form. The term industry is often used by itself to denote manufacturing. However; we speak also of the felling of timber as the lumber industry, the commercial catching of fish as the fishing industry,

and we may even speak of modern, large-scale wheat growing as an industry. Thus it is well to retain the word "manufacturing" in this discussion.

RELATIVE IMPORTANCE OF THE MAJOR GROUPS OF MANUFACTURES IN THE UNITED STATES

It would be geographically interesting to rank the manufacturing industries of the world in the order of their importance. Unfortunately, there is no international system of classification of manufactures, and therefore it is difficult, and in many instances impossible, to add data by industry groups so as to arrive at world totals. However, industry groups can be ranked for a single country, such as the United States. The United States Bureau of the Census has adopted a classification of the manufacturing industries into 20 major groups which serves the country concerned quite well.[1] In order to obtain a fair idea of the relative importance of the groups, various criteria may be chosen, such as value of products, cost or quantity of raw materials used, capital invested, amount of power used, number of employees, or value added by manufacture. No single criterion is perfect for all purposes. The accompanying table gives the value added by manufacture in 1958 and the number of employees in each industry. "Value added by manufacture" is obtained by subtracting the cost of materials, supplies and containers, fuel, purchased electrical energy, and contract work from the total value of the shipments of the manufactured products plus any receipts for services rendered. This difference is further adjusted by taking into account both the value added by merchandising operations and the net change in finished goods and work-in-progress inventories between the beginning and the end of the year. "All employees" includes officers of corporations and also clerical and similar workers in plants and in separate administrative or auxiliary establishments. Of the total of 15,996,000 employees given in the table, 11,644,000 were "production workers," and 4,352,000 were other types of employees. However, all shared in the processes that add value to the basic materials or items that entered into the various manufacturing processes.[2]

What group is the most important? The answer to that question depends upon the mode of grouping and also on which of the various possible criteria is used, in this case whether number of employees or value added by manufacture. It so happens that, perhaps rather unexpectedly for many readers, Group 20, Food and kindred products —which includes such items as meat products, dairy products, canned and frozen foods, grain-mill products, bakery products, sugar, candy, and related products, beverages, and other food preparations—tops the list both in number of workers and in value added. This, of course, is a reflection of the basic fact that, notwithstanding all of the cars, television sets, radios, etc., that people in the United States own, they still have to eat, and eat they do every single day of the year. However, Groups 33 to 38 are really all related because they deal with products made from metals, among which steel is by far the most important, and because to a great extent they involve machinery or items that enter into the manufacture of machinery. Thus by adding these groups a fair measure may be obtained of the role played by machinery in the American economy. Among the other groups, Group 23, Apparel and related products, is important because of the number of workers concerned, while Group 28, Chemicals and allied products, is important for the value added by manufacture.

The sequence of treatment in this chapter does not reflect any attempt at ranking the industries concerned in their importance for the economy, nor are the names of industries used, nor is the grouping always

[1] A detailed discussion of the grouping, definitions, and criteria employed will be found in *Standard Industrial Classification (SIC) Manual,* United States Bureau of the Census, 1957 edition.

[2] For a further discussion of the intricacies of a manufacturing census, the reader is referred to pages XI to XXVII of the *United States Census of Manufactures, 1958,* Vol. III, 1961.

MAJOR GROUPS OF MANUFACTURING INDUSTRIES IN THE UNITED STATES

Census Group Number	Group	Number of all Employees (thousands)	Value Added by Manufacture (millions of dollars)
20	Food and kindred products	1,762	17,533
21	Tobacco products	92	1,413
22	Textile-mill products	917	4,858
23	Apparel and related products	1,188	6,004
24	Lumber and wood products	587	3,177
25	Furniture and fixtures	351	2,349
26	Paper and allied products	578	5,707
27	Printing and publishing	873	7,923
28	Chemicals and allied products	785	12,270
29	Petroleum and coal products	245	2,518
30	Rubber products	336	3,277
31	Leather and leather products	359	1,897
32	Stone, clay, and glass products	576	5,529
33	Primary-metal industries	1,136	11,671
34	Fabricated metal products	1,089	9,412
35	Machinery, except electrical	1,385	12,391
36	Electrical machinery	1,199	10,395
37	Transportation equipment	1,636	15,284
38	Instruments and related products	304	2,906
39	Miscellaneous manufacturing	579	4,754
All industries, total		15,996 *	141,270 *

* Due to rounding off of figures for each of the groups, totals may not correspond.

SOURCE: *United States Census of Manufactures, 1958*, 3 vols., 1961.

exactly similar to those used by the United States Bureau of the Census. To this should be added that in other countries, even in some of the other highly industrialized countries of the world, the relative importance of industry groups or specific industries may well be different. Of course, in the countries with a well-developed power-machine economy the equivalents to the American Groups 33 to 38 would also loom large.

THE CHEMICAL INDUSTRIES

The chemical industries represent one of the major and rapidly developing branches of manufacturing. Not only is the variety of end products of these industries truly astonishing, but hundreds of chemical products become basic raw materials for other manufacturing industries.

The chemical industries obtain some of their principal raw materials directly or indirectly from minerals, such as sulfur and pyrites, ordinary salt or halite, potash salts and phosphates, nitrates, coal, petroleum, and natural gas. Other raw materials are of plant or animal origin; still others come from water and even from the air.

Principal products and branches of the chemical industries. The chemical industries manufacture such a variety of different products that it is difficult to classify them under a few headings.

These industries produce many important acids, among which are sulfuric acid, hydrochloric acid, nitric acid, acetic acid, and citric acid. The alkalies, such as nitrates and carbonates, constitute another group of

chemicals. The sodium carbonates, sometimes found in nature but more generally manufactured from common salt with the aid of limestone, are especially important. This phase of the chemical industry is usually associated with salt deposits, and the alkalies it produces are further utilized in the manufacture of soap. Another important group of chemicals is that of the bleaching compounds, used extensively in the textile industries.

The above are all inorganic chemicals, but production of organic chemicals exceeds them in value, at least in the United States. Organic chemicals enter into many products, such as drugs, dyestuffs, plastics, synthetic rubber, and man-made fibers. They can be derived from animal substances, such as milk proteins, but much larger quantities are manufactured from materials that exist in plants, such as cellulose. Coal tars, the residue of coke manufacture, have long been the major raw material for the manufacture of a host of organic chemicals, such as anilin dyes and aspirin. In recent decades the petroleum industry has furnished more and more comparatively simple basic materials, such as ethylene, propylene, the butylenes, toluene, benzine, etc., for the manufacture of other comparatively simple substances such as ammonia, methanol, alcohol, and styrene, or for that of highly complex substances. The latter are created by polymerization, i.e., artificial building up of large molecules, consisting of multiples of the original molecule. Results are such products as nylon and epoxy resins. In the early 1960's over one third by weight of the output of all chemicals—organic and inorganic—in the United States was of petroleum and natural-gas origin, while the value of these products was close to two thirds. This trend can be expected to continue.

SULFURIC ACID. Sulfur and pyrites (see Chapter 27) serve as the principal basic raw materials for the manufacture of sulfuric acid, a substance which is indispensable in so many industrial chemical processes that the amount of its output is sometimes used as a barometer of activity in the chemical industries. The manufacture of sulfuric acid in the United States began before 1800, and by the early 1960's annual production surpassed 17 million short tons. The United States and Mexico possess the largest stores of crude sulfur; Norway, Japan, Spain, Cyprus, Italy, and West and East Germany are the principal producers of pyrite. The United States, highly industrialized and with well-developed chemical industries, ranks first in the production of sulfuric acid, after which follow the Soviet Union, Japan, West Germany, and the United Kingdom. Also Italy, which still has a not unimpor-



Fig. 350. Chemical plants vary greatly as to size, but many of them are very large, requiring enormous capital investment. This is most of a major plant of the Dow Chemical Co. at Midland, Michigan.

Courtesy Dow Chemical Co.

tant sulfur production, is a manufacturer of the acid. Besides these there are a host of smaller producers. Mexico, though it stands high in sulfur production, is an insignificant producer of sulfuric acid, as it is a little-industrialized country. The markets for pyrites from Spain, Cyprus, and Norway are chiefly in the countries of Western Europe.

FERTILIZERS. The manufacture of superphosphates and potash fertilizers depends primarily upon raw materials—raw phosphates and potash salts—furnished by the mineral industries (see Chapter 27). Potash comes chiefly from the United States, West Germany, East Germany, France, and the Soviet Union (Fig. 346). The manufacture of superphosphates is related less to the deposits of raw phosphate, in northern Africa and Florida, than to the centers of consumption. The industry, therefore, is quite widely scattered. In the approximate order of their importance, the principal manufacturers of superphosphate are the United States, Australia, Japan, Italy, France, Spain, the Netherlands, and New Zealand. The total production of Europe normally exceeds that of North America.*

Nitrogen fertilizers are produced in different parts of the world and in various ways. The soda nitrate mined in Chile has lost its monopoly and now furnishes in normal years only a small percentage of the world's supply. The principal nitrogenous fertilizers are now manufactured by the chemical industry. A major process is the Haber process, a method for the "fixation" of atmospheric nitrogen, i.e., for the synthetic preparation of a nitrogen compound directly from nitrogen in the air. The product is anhydrous ammonia (NH_3). Ammonium sulfate can be made either synthetically, as a derivative of methane (the principal gas in natural gas), or as a by-product of coke manufacture. Also, much ammonium nitrate is produced, mostly via synthetic process. The availability of cheap power, especially cheap hydroelectric power, is a major asset for the synthetic industry. Principal producers of nitrogenous fertilizers are the European Economic Community, the United States, Japan, the United Kingdom, East Germany, Poland, Norway, and Canada. No data are available for the Soviet Union.

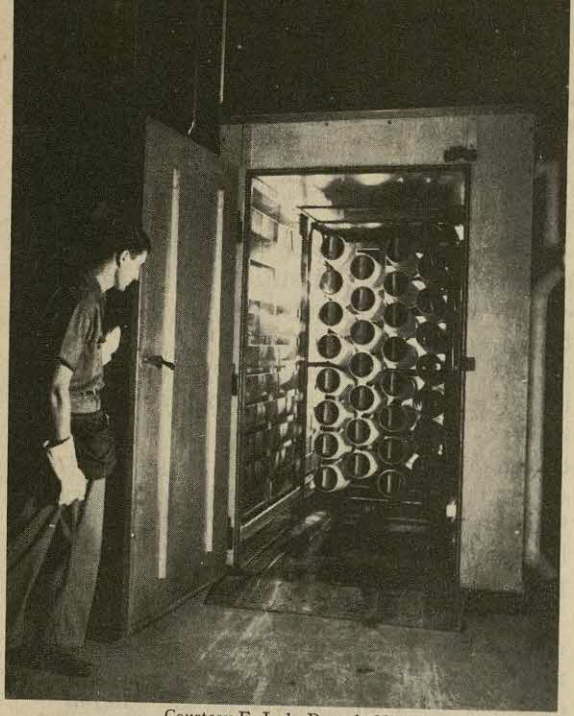
INDUSTRIAL EXPLOSIVES. Part of the industrial-explosives industry is closely associated with the manufacture of nitrogen fertilizers. Its products, especially dynamite, are used extensively in quarrying and mining. The industry is rather highly decentralized because of the danger involved in the manufacture of some of its products and in the transportation of many of its finished products; the plants are therefore located mostly in country districts rather than in cities.

DYESTUFFS. Dyestuffs hold high rank among the various chemical products. In most parts of the world the old, natural dyes obtained from the vegetable and animal kingdoms have been supplanted by the much cheaper synthetic products. The principal raw material is coal tar, a by-product of the coke industry, which can easily be obtained wherever coking coal is available. Because of the intricate processes involved, the industry has developed only in the more advanced industrial countries of the world, especially in Europe and the United States.

Coal-tar dyes were made first in Germany, which until World War II was the world's largest producer. As a result of that war, the United States replaced Germany in the world market and is now by far the leading producer. Well over half of the United States plants are located in New Jersey, New York, and Pennsylvania. Other important producers are England, the Soviet Union, Japan, France, Italy, and Switzerland. West Germany and Switzerland consistently export dyestuffs in excess of their imports.

PAINTS AND VARNISHES. Raw materials for the manufacture of paints, varnishes, and related products are furnished by other branches of the chemical industry and by closely allied industries. The industry is quite widely scattered and plays a relatively unimportant role in international trade; it is generally cheaper to ship the pigments than the finished products. In the United

* No reliable data are available for the Soviet Union.



Courtesy E. I. du Pont de Nemours and Company

Fig. 351. Nylon yarn being baked in "twist setting oven" before being wound on spools and cones for shipment from the du Pont plants at Seaford, Delaware, and Martinsville, Virginia.

States the principal centers of production are in the industrial East (New Jersey, New York, Ohio, Pennsylvania) and in Illinois and Michigan. Michigan developed paint manufacturing in response to the needs of the automobile industry. Also California has a fair-sized industry.

SOAP AND OTHER DETERGENTS. Soap is made from animal or vegetable fats with the aid of alkalies, such as soda or potash. The principal fats used are tallow, coconut oil, babassu oil, cottonseed oil, palm-kernel oil, peanut oil, olive oil, and others.

In recent years synthetic compounds have been made with much better detergent power (which is the power to remove oil and grease or solid particles, "dirt," dispersed in oil) than soaps have. These compounds are now commonly referred to as "detergents" and are the result of highly complicated chemical-manufacturing processes. At the present time production of detergents is more than double that of soaps in the United States. The manufacture of soaps and detergents is fairly widespread in the United States. Leading states are New Jersey, Ohio, California, Illinois, New York, and Massachusetts.

In the realm of foreign production the fine-textured, scented soaps of France and England still are top favorites with the trade, followed closely by high-grade Italian soaps.

PLASTICS AND FIBER SYNTHETICS. When two British chemists found in 1856 that they could make a substance resembling ivory by soaking rags or paper in acid and mixing them with camphor into a doughy mass, they were laying the foundations for an industry that would some day be able to replace wood, glass, cotton, wool, and silk for a wide variety of purposes. In 1869 important changes in the process were introduced by an American, and the resulting material, known as celluloid, became the first American plastic. Though this ivorylike material soon became popular for such things as piano keys, combs, and knife handles, inflammability was long a disadvantage. Not until the rise of radio in the 1920's created a demand for molded cases did plastics begin to come into their own as a competitor with cabinet woods.

Today plastics are made in many different ways and from different basic materials. A number are created by polymerization of comparatively simple substances, such as ethylene, formaldehyde, and phenol. They are also made synthetically from simple substances derived from coal, petroleum, air, water, and limestone. Among these are nylon and acrylic fiber such as orlon and Acrylan. Rayon is obtained by means of chemical treatment of cellulose, a carbohydrate which constitutes the skeletal material of plants. Cotton contains about 90 per cent cellulose, the wood of coniferous trees about 60 per cent. Cellulose acetate is made by treating cotton linters with acetic acid and acetic anhydride. It is the raw material not only for the manufacture of certain plastics but also for that of *acetate* rayon, or "acetate," the earliest of the synthetic textiles. Wood pulp is the source of cellulose for the manufacture of *viscose* rayon, a slightly different product. Wood pulp is treated with caustic

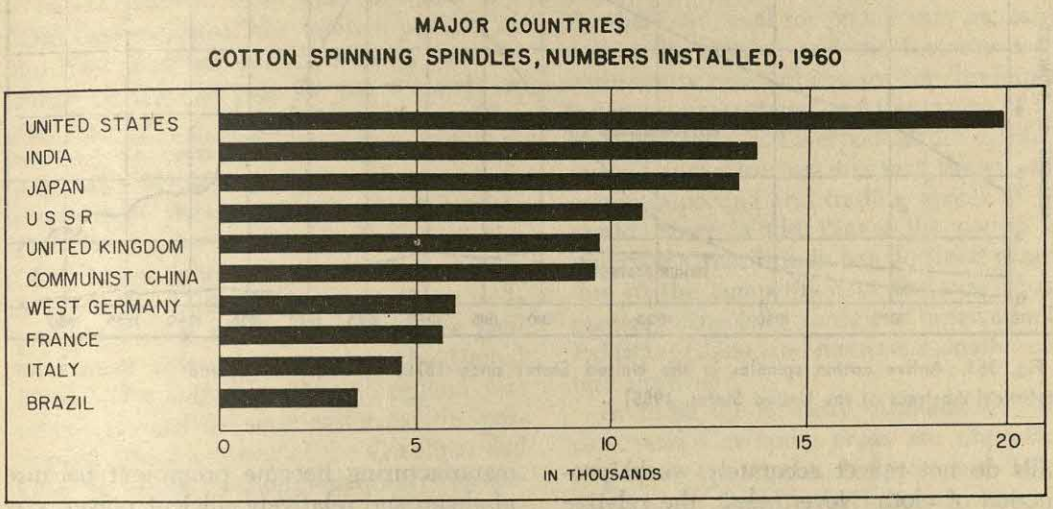


Figure 352.

soda and bisulfide of carbon to make a gelatinous mass which is extruded through a finely perforated nozzle to make the fibers which then are hardened in a chemical bath.

It is difficult to exaggerate the profound and increasing effects of synthetic materials upon the textile industry, furniture, and building industries. In the United States the industries that make plastic materials –fibers excluded–are well distributed over the country, but Pennsylvania, New Jersey, and New York lead in production. Cellulosic fibers and noncellulosic fibers are manufactured especially in the South Atlantic states and provide the materials from which are woven the many types of synthetic cloth. At present noncellulosic fibers are more important than cellulosic (Fig. 355).

TEXTILES AND TEXTILE PRODUCTS

The textile and textile-products industries can be divided into three principal groups; they are those manufacturing (1) textiles, (2) wearing apparel, and (3) cloth articles other than clothing. The first group includes all spinning, weaving, and knitting mills, and its manufactures provide the raw materials for the other two. The raw materials used by the textile industries are chiefly cotton, rayon, nylon, wool, linen, and silk. In quantity used, cotton still outranks the other materials, although synthetic materials have become increasingly competitive.

The textile industries include the manufacture of the various kinds of yarn and also of cloth, such as cottons, woolens and worsteds, linens, silks, rayon and nylon cloths, knit goods, and cloths made of mixed yarns. While the manufacture of artificial fibers is a phase of the chemical industries, the making of cloth is a textile industry.

The cotton textile industry. Among the textile industries the manufacture of woven cotton goods is far in the lead, both in the United States and in the entire world. In the former the "value added" by weaving of cotton is more than double that added by the weaving of synthetics and three times that added by the weaving and finishing of woolen goods.

World distribution of cotton textile manufacturing. The demand for cotton textiles is world-wide. While other materials may be in greater favor locally and for specific purposes, nearly all the people of the earth make use of cotton fabrics in some form. In the warm and in many intermediate climates cotton textiles rank supreme; only in the regions of distinctly cool to cold climates do they yield first place to wool and fur. Since large quantities of cotton still go into the manufacture of homespun goods, the statistics of cotton consumption by yarn

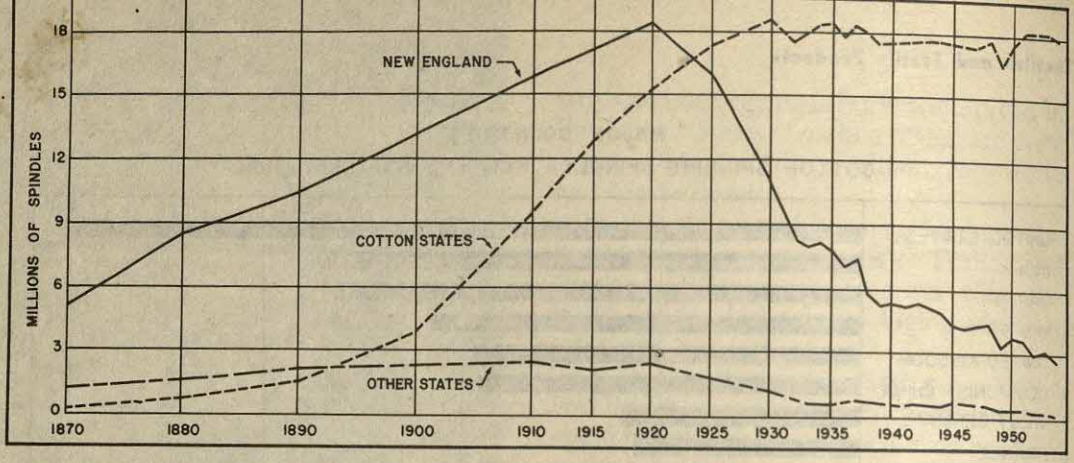


Fig. 353. Active cotton spindles in the United States since 1870, by regions. (Source: Statistical Abstract of the United States, 1955)

mills do not reflect accurately world production of cloth. Nevertheless, the relative importance of the various countries in cotton manufacturing can be gauged fairly well by the number of spindles used in spinning as shown in Fig. 352. In the early 1960's the cotton textile industry of the United States accounted for about 16 per cent; that of the European Economic Community, for 15; of India, for 11; of Japan, for 11; of Russia, for 9; of China, for 8; and of the United Kingdom, for about 6 per cent of the total number of spindles in the world. Other producers of note are Brazil, Spain, Poland, and Czechoslovakia. The total number of countries that make cotton yarn and cotton cloth is quite considerable. It is noteworthy that the countries of Europe west of the USSR all manufacture cotton goods, although practically no cotton is produced.

The cotton textile industry in the United States. The most outstanding development of the last half century in the cotton textile industry of the United States has been the shift in geographical distribution of factories from New England to localities nearer the raw material. In the first half of the nineteenth century, when machine methods of manufacture were becoming established in this country, the streams flowing from the glacial lakes and swamps of New England, with their small falls and rapids, provided easily harnessed power resources. The streams had a fairly uniform flow of clear water, and through the building of small dams numerous additional storage reservoirs could be created. Textile manufacturing became prominent because of cheap and relatively efficient power, raw materials readily obtainable by coastwise traffic, large markets available in the nearby city centers, and the mechanical ingenuity of the New Englanders. Agriculture in New England was finding it difficult to compete with the farm products from the new lands beyond the Alleghenies, and thus a supply of labor became available from adjacent country districts. When steam power came into prominence, it served to supplement the water power, in many instances even to supplant it; but the acquired skill and the large capital investments served to keep New England's supremacy in textile manufactures undisputed until after 1900, as the following table indicates.

Distribution of Active Spindles in the United States by Percentages of the Total

	Southern States	New England	Others
1870	4.6	77.1	18.3
1880	5.3	81.0	13.7
1890	10.9	76.1	13.0
1900	22.4	67.6	10.0
1910	37.2	55.6	7.2
1920	42.9	51.5	5.6
1930	59.4	36.3	4.2
1940	74.8	22.4	2.8
1950	81.0	17.1	1.9
1954	87.2	12.2	0.6
1961	93.7	6.0	0.3

SOURCE: *Statistical Abstract of the United States*, published annually, United States Bureau of the Census. Various years.

In comparison with what are now the "Old Cotton States," the relative position of the New England cotton industry has declined during the past 50 years, slowly at first and later at an accelerated rate. The number of active spindles grew steadily until after World War I, though at a much slower rate than in the South; but after 1920 the number declined, whereas in the Old Cotton States it increased (see Fig. 353). In the early 1960's the southern mills processed close to 95 per cent of the total amount of cotton consumed in the United States. The shift from New England was mainly toward the southeastern states, particularly the Piedmont of the Carolinas and Georgia. Lesser development occurred somewhat later in northern Alabama with some in eastern Tennessee. Texas, a small producer of textiles, now consumes more cotton than Massachusetts does (see Fig. 354).

As might be expected, those phases of textile manufactures requiring the least skill moved first, while those dependent upon quality of output were slowest to shift.

The cotton textile industry in Europe and elsewhere. The cotton industry of the European Economic Community is scattered through all of the member countries. In France the industry is located mainly in the east, near the Vosges Mountains, and near Rouen on the lower Seine river; in Italy, in the upper Po basin; in Belgium, in Flanders; and in the Netherlands, in the northeastern part of the country. In West Germany the industry is fairly well distributed, but with concentrations to the west of the Ruhr industrial district, between it and the Dutch border; in the southern part of the Ruhr area; across the border from the Dutch cotton area; and finally in southern Germany, between the upper Danube and the upper Rhine.

The cotton industry in Great Britain is concentrated in the Lancashire district, Manchester being the principal center. Before artificial means had been devised to maintain a desirable degree of humidity in the factories, the damp climate of Lancashire, caused by its location on the west side of the Pennine Mountains, was of great advantage for cotton manufacturing. This advantage is still of some economic value. Furthermore, coal for power was available within the district, and the factories were within easy reach of the sea for the importation of raw material and the export of the finished products. Liverpool at the entrance to the Lancashire area was long the greatest cotton-importing and trading center of the world. Since World War I the cotton industry of Great Britain has declined greatly due to the competition of the new textile centers, especially those in Japan, India, Pakistan, China, and numerous smaller centers elsewhere.

In India the Bombay, Ahmadabad, Madras, and Cawnpore areas are important; in Japan, the Osaka, Nagoya, and Tokyo regions; in Russia, the Central Industrial District (the general area around Moscow), with new mills being created in the Turkestan and Transcaucasia regions.

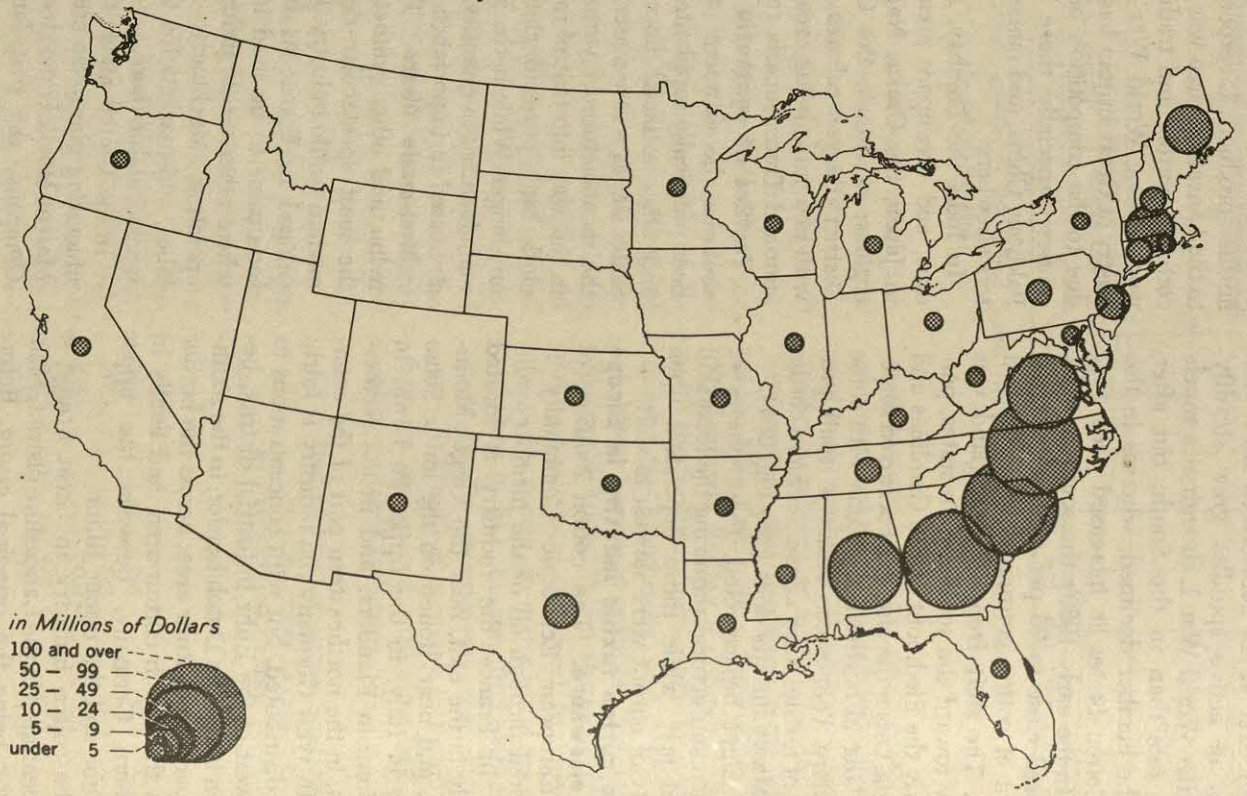
Textiles of synthetic fibers. Silk, for centuries the aristocrat among fibers, has been practically supplanted by rayon, nylon, and other artificial fibers. In the United States silk as a raw material still enters into the manufacture of yarns and thread, and in this way into that of mixed-yarn types of cloth. Little pure silk cloth is manufactured any longer. While in the Far East silk is still manufactured in quantity, it has also greatly decreased in importance.

Man-made fibers. The rise of rayon, nylon, and other synthetic fibers has been the most spectacular development of the modern textile industry. Rayon was first developed in France as "artificial silk" and soon came to be used in several countries where other textile industries were already operating. Machinery, technically skilled labor, and markets for the finished textiles were available there.

In the United States the first rayon-manufacturing plant was established in 1911 at Marcus Hook, Pennsylvania, by the Viscose Company, the first large American producer. In 1917 a second plant was added, at Roanoke, Virginia. Soon many other plants were established in the area from Georgia to New England. The early rayon product was very shiny and weak. Gradually quality was improved, until a fine, soft,

BROAD WOVEN FABRIC MILLS, COTTON: SIC 221

Value Added by Manufacture by State: 1958

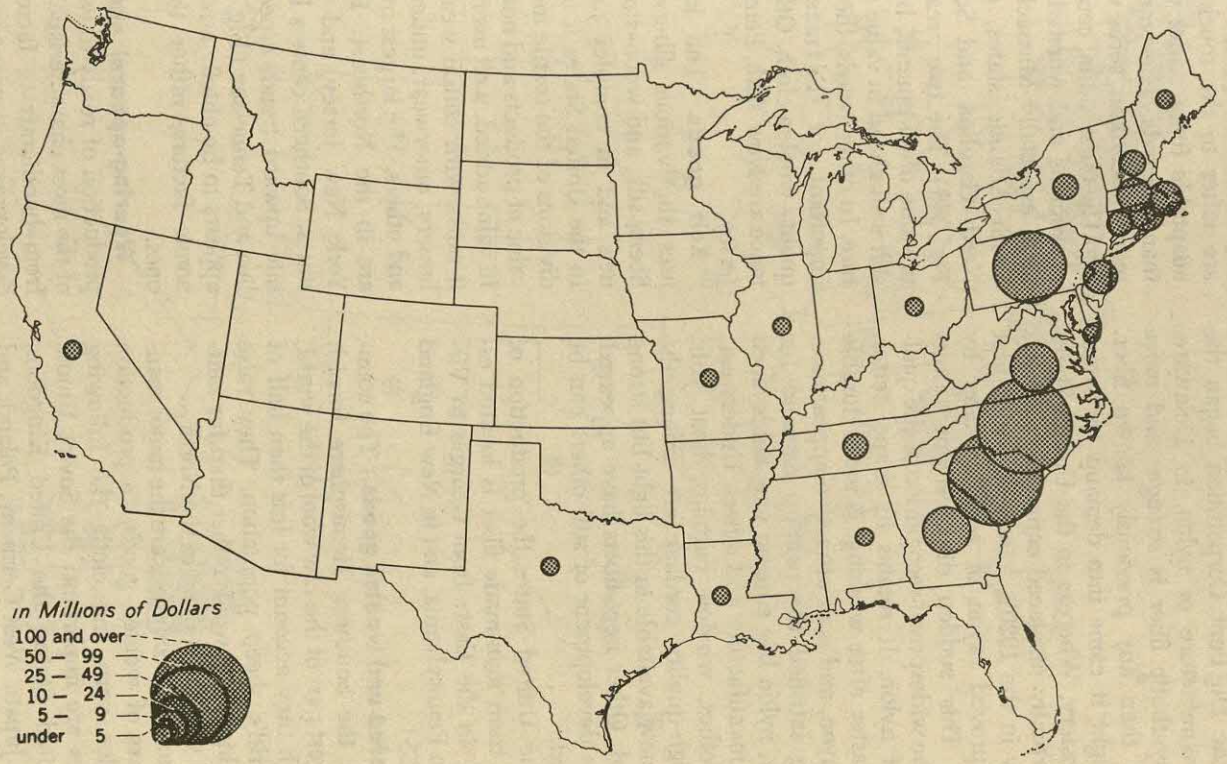


Bureau of the Census. M-58-D 221

Figure 354.

Broad Woven Fabric Mills, Man-Made Fiber and Silk: SIC 222

Value Added by Manufacture by State: 1958



Bureau of the Census. M-58-D222

Figure 355.

lustrous, durable thread was produced, very popular for the manufacture of a wide variety of woven and knitted goods.

A more recent development in the textile industry has been the rise of nylon. In 1939 the Du Pont Corporation began the first manufacture of nylon, in Delaware. This synthetic fiber is stronger and more elastic than any previously known fiber. Overnight it came into demand for women's hosiery. Whereas in the United States silk virtually displaced cotton for women's hosiery in the 1920's, it was displaced first by improved rayon or acetates, later by nylon. This sudden displacement results from the widespread recognition of the qualities of nylon. It retains its shape better, dries faster after washing, is more durable than rayon, and is of attractive appearance. Having satisfied the pent-up demand for hosiery, nylon has entered new fields, such as tire manufacture and others. Underwear, nightclothes, window curtains, boat sails, and high-quality cordage are among the goods now available in this light but strong material. Other new fibers have appeared, and the development of still others can be expected.

In the United States the production of fabrics from man-made fiber is located especially in the East: from Georgia to Virginia, in Pennsylvania, and in New England (Fig. 355).

Worsted and woolen goods. The countries of the Southern Hemisphere furnish the largest part of the raw wool of the world, although they account for less than half of the world's sheep population. They raise sheep chiefly for wool, rather than for mutton and wool as is done in the North.

The northern countries are the major manufacturers of woolen goods. In production of woolen yarn and cloth, the following countries are important: the Soviet Union, the United States, the United Kingdom, France, Japan, West Germany, Poland, and Czechoslovakia. As an exporter of wool products the United Kingdom holds an important position. High quality of the woolen goods and splendid connections with market areas are favorable factors.

In the United States weaving and finishing mills for woolen goods come third in number of employees and value added by manufacture, after cotton weaving and weaving of synthetics. Woolens are more popular as an apparel fabric because they are softer to the touch and are therefore adaptable for a wider variety of garments than worsteds. The worsteds, with threads more closely knit, serve well for men's clothing. The outstanding centers of manufacture of woolens and worsteds are in New England, especially Massachusetts, and in the South Atlantic states, especially Georgia, North Carolina, and South Carolina (see Fig. 356). The two areas are almost equal in value of shipments, but New England is still well ahead in value added by manufacture. In other words, the latter area is more important for the manufacture of high-quality woolen cloth. Other states of importance are New York, Pennsylvania, and New Jersey.

Knit goods. The knit-goods industry uses the various fibers—cotton, synthetic fibers, silk, and wool—singly for some products and in complex mixtures for others. In the United States it is one of the major divisions of the textile industries, both as to value of products and number of employees. In value added, well over one billion dollars, it ranks with cotton weaving. Products are hosiery, outerwear, underwear, knit fabrics, and others. The largest manufacturing areas are in the Northeast: Pennsylvania, New York, New Jersey, and the New England states. Southern centers have shown a definite upward trend, especially North Carolina and Tennessee (Fig. 357). Localization appears to be chiefly a result of purely economic factors, rather than of geographic ones.

Wearing-apparel manufactures. The production of ready-to-wear clothing is one of the most characteristic results of the shift from handicraft to factory methods. This development is pronounced in the United States, where the great majority of the men and a high percentage of the women buy ready-made clothing. In the Old World the tailors and dressmakers to a considerable extent still make clothes to order, while in the humbler homes the housewives often do

BROAD WOVEN FABRIC MILLS, WOOL: INCLUDING DYEING AND FINISHING: SIC 223

Value Added by Manufacture by State: 1958

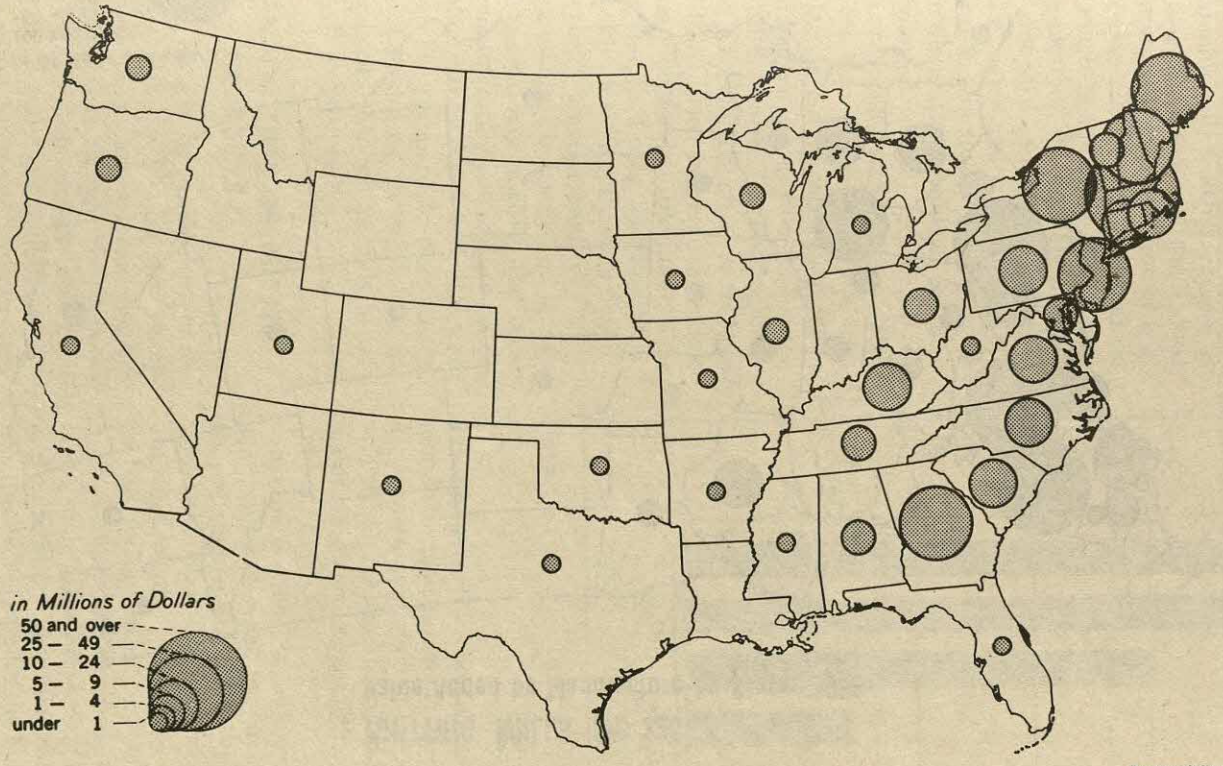
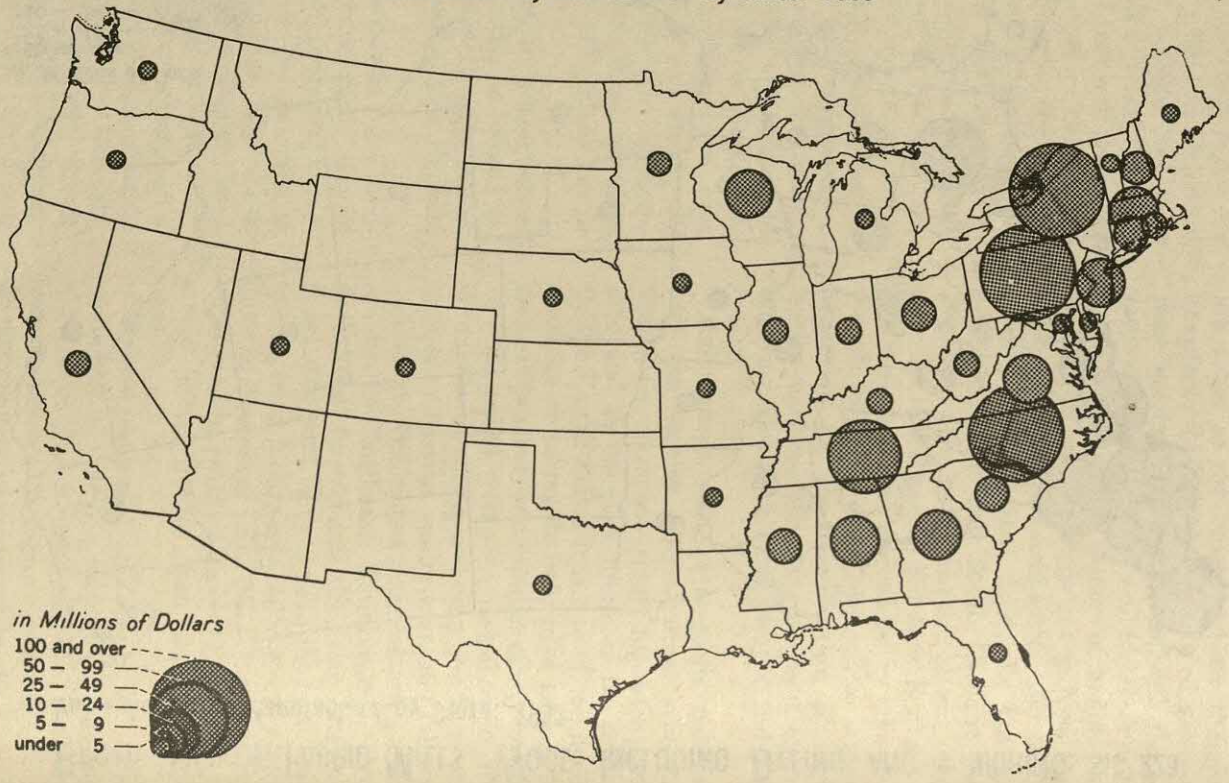


Figure 356.

KNITTING MILLS: SIC 225

Value Added by Manufacture by State: 1958



Bureau of the Census. M-58-D225

Figure 357.

much of the garment making, particularly for the women and children. During the last half century, however, the manufacture of ready-made clothing for men, women, and children has made great strides in Europe.

The manufacture of wearing apparel is one of the major industries of the United States, employing well over a million people, and with a value added of over six billion dollars. Inasmuch as the labor force is exceptionally important, the clothing industry tends to be associated with great population centers. While manufacture of wearing apparel is found in practically all important cities—and in that sense it is among the most widely distributed urban industries—the main centers are located in the largest cities. The New York-New Jersey industrial area holds first place in both men's and women's clothing, but has a much greater lead in the latter than in the former. The Philadelphia-Camden and Chicago industrial areas hold second and third place respectively, while other important centers are Baltimore, Boston, Los Angeles, St. Louis, and Rochester. Many other cities have locally or regionally important wearing-apparel industries.

Taken as a whole, the textile and textile-products industries are among the most important manufacturing activities of nearly all industrial countries. Since they deal with necessities of life comparable only to the preparation of foodstuffs, their relative importance continues through periods of adversity as well as prosperity.

THE MANUFACTURE OF RUBBER PRODUCTS

The rubber industry is to some extent related to that of the textiles in that many rubber manufactures have a fabric or cord base. Rubberized cloth for rainproof apparel and rubber boots and shoes were among the earliest products, and their manufacture is still a phase of the industry. During recent decades the great demand for rubber in Anglo-America and in Europe has been for automobile and truck tires, while in Europe the bicycle also continues to be a consumer.

Rubber in the United States. In the United States the output of rubber products has increased tremendously since the automobile became important. The country buys a considerable portion of the world's supply of natural rubber and, in addition, is the major producer of synthetic and reclaimed rubber (Fig. 358).

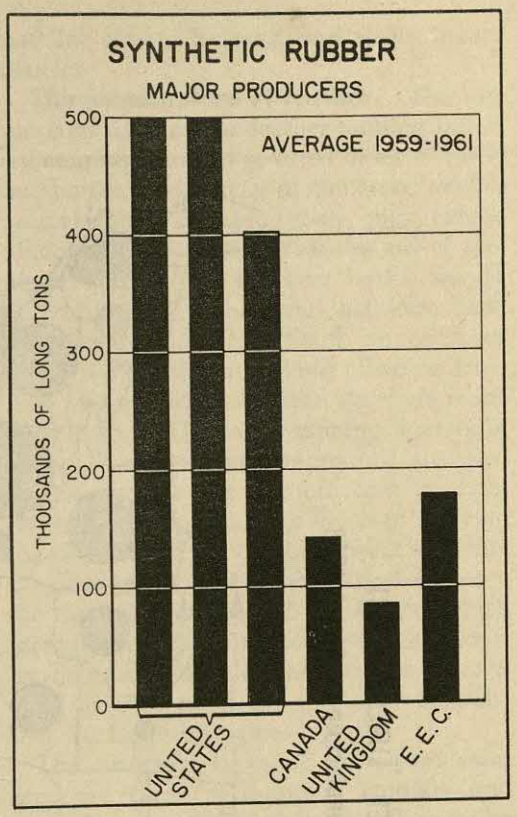
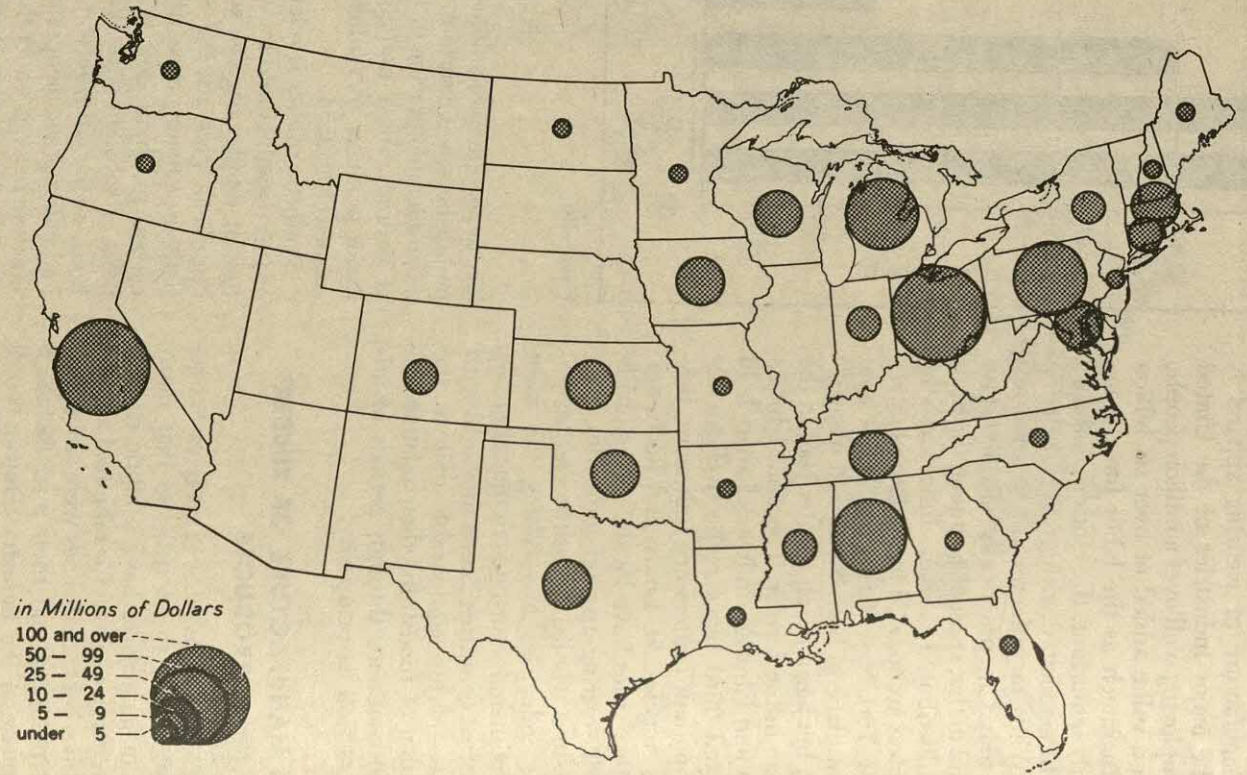


Figure 358.

Synthetic rubber is related to the plastics, as it is manufactured by way of polymerization of simpler organic substances, such as butadiene plus styrene (buna S rubber), both petroleum derivatives consisting of carbon and hydrogen, and other hydrocarbons or substances derived from hydrocarbons, such as isobutylene (butyl rubber) and chloroprene (neoprene rubber). Its manufacture belongs under the heading either of the plastics or the chemical industries in general. The table below gives the amounts of natural, reclaimed, and synthetic rubber used in the United States in 1940 and 1961. Synthetic rubber, which can now be produced in competition with natural rubber

TIRES AND INNER TUBES: SIC 301

Value Added by Manufacture by State: 1958



Bureau of the Census M-58-D301

Figure 359.

on the basis of cost, will undoubtedly continue in large production because it has certain qualities which natural rubber does not have.

DOMESTIC CONSUMPTION OF RUBBER IN THE UNITED STATES

Kind of Rubber	1940 In long tons	1961
Natural (imports)	818,624	425,441
Reclaimed	208,971	246,910
Synthetic	2,940	1,086,152

SOURCE: *Statistical Abstract of the United States*, United States Bureau of the Census, 1948 and 1962.

Ohio holds a commanding lead in the manufacture of tires and tubes and also ranks well in the manufacture of other rubber articles. Akron, which ordinarily accounts for nearly half of the tire production of the United States, is often referred to as the "rubber capital of the world." There are manufactures of rubber products in a number of other Ohio cities as well, particularly in Cleveland, Youngstown, and Columbus. The kinds of products are legion, including such diverse items as rubber boats, tubes and hose, gaskets, rubberized cloth, and hard-rubber articles (Fig. 359).

Southern New England (Massachusetts, Connecticut, and Rhode Island) constitutes an important area for the manufacture of rubber footwear. Rubberized wearing apparel is made in New Jersey and southern New England. The manufacture of rubber footwear is limited mostly to the Northeast, but that of tires and inner tubes—except for the concentration in Ohio of about one third of the production—is spread over a number of states. Major centers of production of fabricated rubber items are Ohio, Massachusetts, and New Jersey, which together account for almost half. However, there is smaller production in many states.

LEATHER AND LEATHER GOODS

Leather serves many purposes. The bulk of it is made into footwear, but considerable quantities are used for machinery belting for the transmission of power in factories and for gloves, luggage, and many luxury articles.

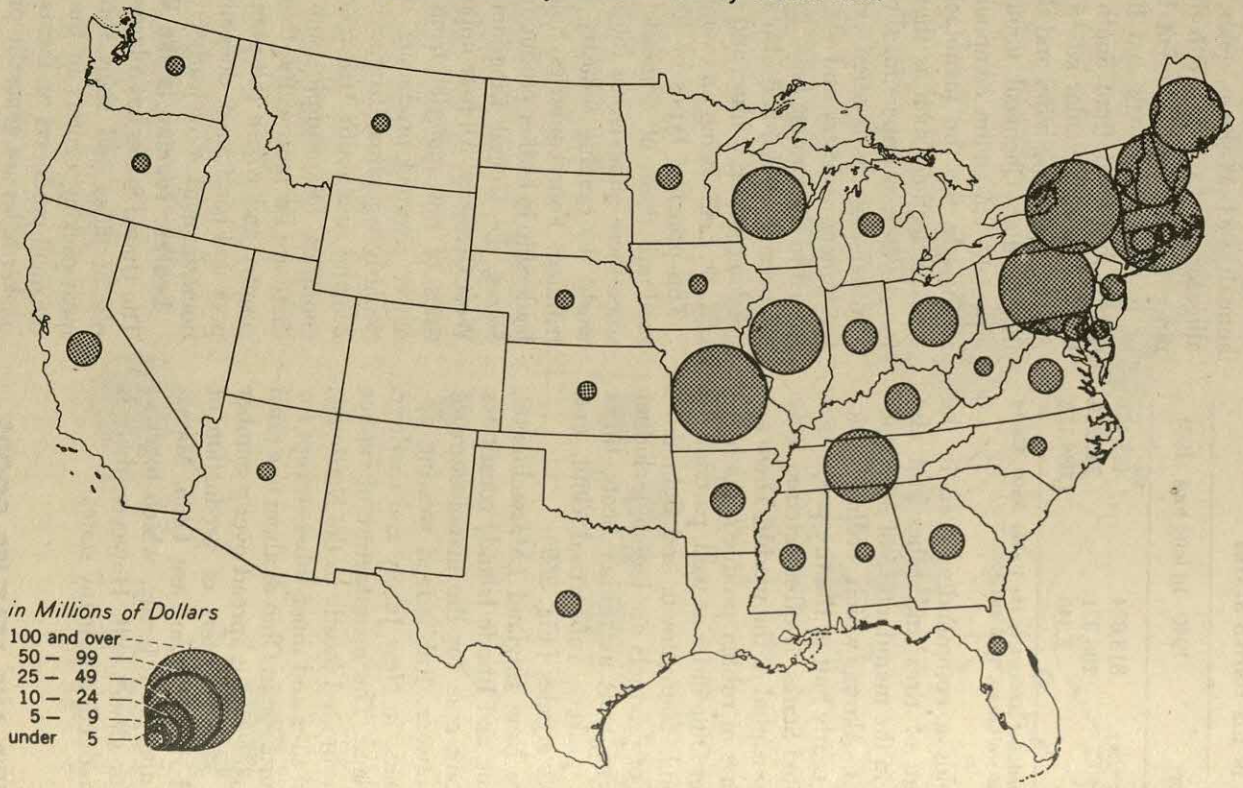
The manufacture of leather. The raw material used by the leather-tanning industry consists of salted or dried hides of cattle and horses and the skins of numerous smaller animals, such as sheep, goats, pigs, calves, alligators, and snakes. With the aid of tannin extracted from different barks, woods, or fruits—such as oak and hemlock bark, quebracho wood from South America, or the cup of a particular kind of acorn from Asia Minor—these hides and skins are made into leather. Chemical tanning materials, especially chromium compounds, are used extensively for the manufacture of light types of leather, such as those in demand for gloves or as uppers for shoes. Originally a rather close association existed between the tanning industry and the forests which furnished the tanning bark. Later the industry became established also where there is good access to raw hides and consumer markets, St. Louis being an example.

The principal types of hides and skins used are those of domestic animals, and since these animals are found all over the world the tanning industry is widely distributed. Four countries hold outstanding leadership in leather production: the United States, the United Kingdom, France, and West Germany. All four import large quantities of raw material from some of the newer livestock-producing countries, particularly Argentina, Uruguay, Australia, New Zealand, and South Africa, or from tropical countries, for example from India, where there are far more cattle than in any other country and where the population, mostly poor and barefooted, does not offer a great domestic market for leather.

Leather tanning in the United States. The United States has a large domestic supply of hides and skins furnished by the meat-packing centers in the Midwest and by small producers on farms. The so-called packer hides are generally preferred by the tanning industry because of greater uniformity of workmanship, and they constitute the principal domestic supply. Considerable quantities of hides and skins are imported.

FOOTWEAR, EXCEPT RUBBER: SIC 314

Value Added by Manufacture by State: 1958



Bureau of the Census M-58-D314

Figure 360.

The geographic distribution of the leather tanning and leather finishing industry within the country still reflects to some extent the influence of two principal tanning materials: oak bark and hemlock bark. The oak tree is most common in the Appalachian Mountains, from Pennsylvania southwestward, while the hemlock occurs farther north in a belt which reaches from New England westward to Wisconsin. Tanning and finishing are important in Massachusetts, Wisconsin, New York, New Jersey, and Pennsylvania. The latter state owes its position partly to early availability of oak bark and partly to the fact that Philadelphia was the center of origin of chrome tanning.

Leather-goods industries. Shoes and boots rank first among the various products of this industry.

In the United States the oldest and foremost center of shoe manufacturing is in eastern Massachusetts and the nearby portions of New Hampshire and Maine (Fig. 360). During recent decades the New England shoe industry has lost some ground to rival centers developed elsewhere. The New York industrial region is especially noted for women's shoes. There are other shoe-manufacturing centers in southeastern Pennsylvania. The footwear industry has shown a marked development in the states farther west. Missouri now ranks second in value of output of boots and shoes, the St. Louis industrial area being the chief center. Illinois and Wisconsin also are important shoe-manufacturing states, with large factories at Chicago and Milwaukee.

The principal glove-manufacturing district in the United States is located in the Mohawk Valley of upstate New York, where the towns of Gloversville and Johnstown manufacture nearly half of all the gloves made in this country.

Among the foreign countries that have an important shoe industry, England is known for its excellent qualities of men's footwear. The French, Swiss, and Italian shoe industries are outstanding because of quality and luxury production, primarily of women's shoes. French and English gloves are in demand the world over.

THE MACHINERY-MANUFACTURING INDUSTRIES

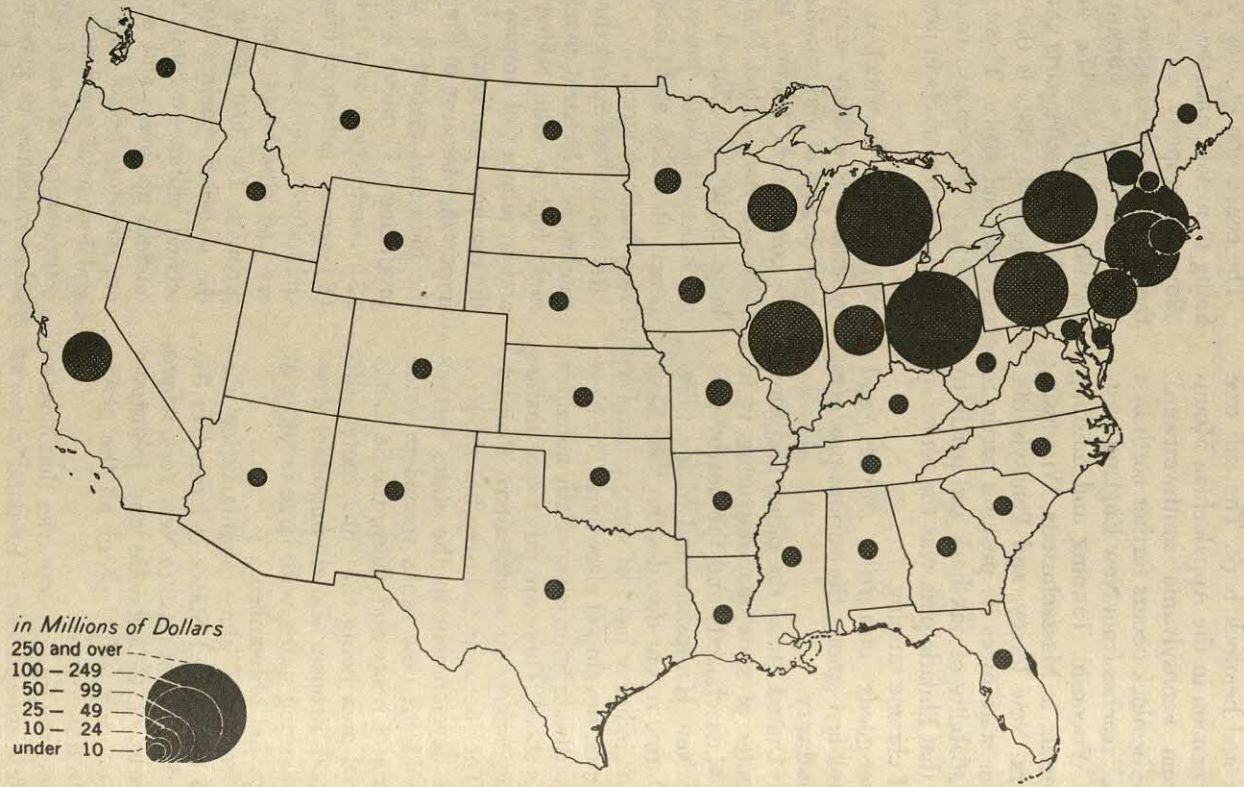
The conversion of ores to metals, the refining of metals, and the manufacturing of alloys are properly within the province of the metallurgical industries, that is, the iron and steel, copper, aluminum, and other metallic industries. The shaping of these metals into specific parts and their assembly into workable units is the province of the machine industries. These industries have developed in response to available skilled labor and to markets in need of their products.

The extent to which countries produce machinery is a fairly accurate criterion of their degree of industrialization. Many of the countries of Europe, the Soviet Union included, the United States, and Canada have highly developed manufactures of machinery. In Asia, Japan attained prominence after 1920, and China and India have lately made progress.

In the United States the manufacture of machinery, electrical machinery excluded, ranks high in value added by manufacture and in number of employees. Branches of the machinery industry which are of special importance because of their relationships to the industrial system in general are those producing (1) metal working machinery, (2) construction and related equipment, (3) general industrial machinery, (4) special-industry machinery, (5) farm machinery and equipment, and (6) engines and turbines. The first group covers primarily the so-called machine tool industries; the second embraces construction machinery, oil-field machines and equipment, conveyors, elevators, hoists, and similar items. General industrial machinery refers to pumps, compressors, ball and roller bearings, and other machines of general use in industry. Special-industry machinery includes machines designed for the manufacture of textiles, food products, wooden objects, and paper and for printing and other special purposes. A few of these industries are discussed briefly.

METALWORKING MACHINERY AND EQUIPMENT: SIC 354

Value Added by Manufacture by State: 1958



Bureau of the Census M-58-D354

Figure 361.

Metal working machinery. This industry is of basic importance because it produces the machines, such as power drills, lathes, saws, shears, and forges, that are necessary in the manufacture of all other machines. On the basis of the number of wage earners employed, the leading centers are located in Michigan, Ohio, and Illinois; Pennsylvania, New Jersey, and New York; and southern New England. There is no clear-cut differentiation in the products made, and it seems evident that the chief requirement for location is accessibility to the factory centers which need prompt service in providing and maintaining the machines concerned (Fig. 361).

In the category of special-industry machinery the manufacture of food products machinery now outranks that of textile machinery in the United States. However, the manufacture of textile machinery is still important in the United States and other parts of the world. Textile machinery includes machines and equipment used in all kinds of textile mills and for all processes, from working raw stock to finishing the finest fabrics. This industry flourishes to a greater or lesser degree in connection with textile manufacturing in the various countries. Those regions which have or have had large textile industries have important textile machinery manufactures. This is true in the United States, the United Kingdom, France, West and East Germany, and Italy. Countries of recent importance in textile manufacture buy more of their textile machinery in the older areas. Because of the frequent changes in textile technology, plants must buy improved machinery to keep abreast of their rivals in this highly competitive industry. In the United States, Massachusetts still holds first rank, followed by Pennsylvania. This industry has been successfully maintained in the Northeast despite the southward movement of the cotton textile industry. It is noteworthy, however, that textile machinery factories are beginning to develop in the Southeast, particularly in the Carolinas.

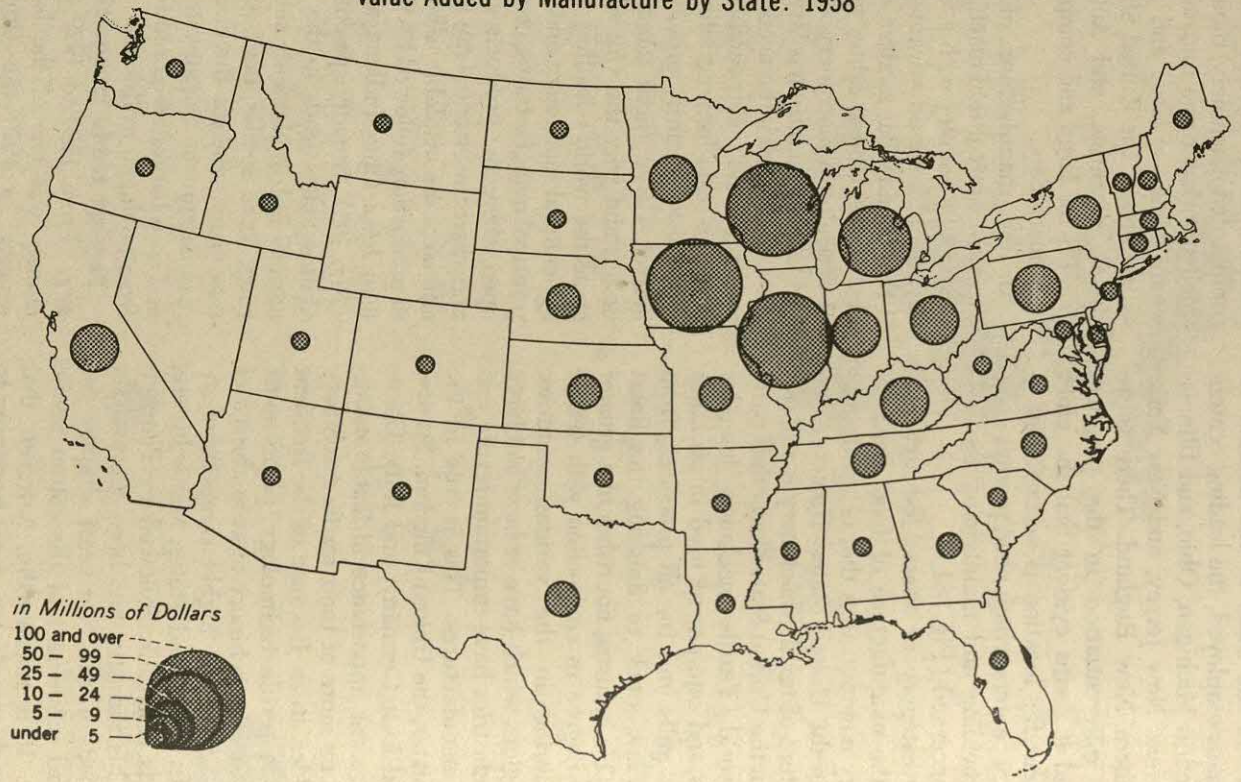
Farm machinery and equipment. Every nation uses agricultural implements of some kind in connection with its farming activities. Where labor is very plentiful and cheap, as in India or China, the equipment in general still is simple, most of it being tools such as spades, hoes, rakes, and flails. Where fields are small and labor is only moderately plentiful, as in Sweden and France, more complicated machinery, though of relatively small size, has come into use. In countries where fields are large and labor is scarce, as in Canada, the United States, the Soviet Union, Argentina, and Australia, the demand is for large and complicated agricultural machinery.

In the manufacture of complex and expensive agricultural machinery, it is inevitable that a country with a large home market should have an advantage, particularly if that country has modern industrial facilities. In the United States the manufacture of agricultural machinery is favored by the fact that the country has large iron and steel plants from which the needed iron and steel rods, bars, and sheets can be obtained, while the large-scale farming which characterizes much of the country provides a substantial market. Given these factors it is easy to understand why the United States has become the world's leading manufacturer of agricultural machinery and equipment. The principal manufacturing centers have developed where the products are most needed and where the essential raw materials, power, and labor are available. Illinois is the leader in production, followed by Wisconsin, Michigan, Iowa, Ohio, Indiana, and Pennsylvania (Fig. 362). Broadly speaking, northeastern United States leads in the manufacture of agricultural implements such as wheelbarrows, forks, spades, hoes, axes, and smaller machinery, whereas the principal centers of manufacture of tractors, trucks, combines, and corn harvesters are in the central states from Michigan to Illinois.

Foreign trade in agricultural machinery. From 1920 to 1929 agricultural machinery was one of the leading American exports. In 1929 the United States sold abroad over 140 million dollars' worth of farm machinery, or about half of the output that year. Chief customers were Canada, Argentina, and the Soviet Union. The depression years of the 1930's wrought havoc

FARM MACHINERY AND EQUIPMENT: SIC 352

Value Added by Manufacture by State: 1958



Bureau of the Census M-58-D352

Figure 362.

with this business, but in the postwar period exports of agricultural machinery have soared again, no doubt in response to the pressing needs abroad for machinery to help rebuild the facilities for food production. In the early 1960's the principal customers for American farm machinery were Canada and Latin America and some countries of Western Europe and the Far East.

THE TRANSPORTATION EQUIPMENT INDUSTRIES

Equipment with which to move people and goods may quite properly be considered one of the fundamental material needs of modern man. The stage of industrial civilization attained by any people is indicated by their modes of transportation. Those highest in the scale motor over land and sea or through the air; those lowest in the scale walk on land or paddle their way over sheltered waters in crude canoes. The industrially progressive countries have made great advances in building railroads, steamships, and motor vehicles.

In the United States the transportation equipment industries, taken collectively, constitute one of the leading manufacturing groups of the nation, both in number of employees and value added.

During World War II the manufacturing of transportation equipment in the United States increased more than any other industrial activity except that of making munitions. In the years of peak production—1943 and 1944—when total manufacturing in the United States was 78 per cent above prewar (1939) production, the manufacture of automotive vehicles was up 80 per cent, while that of ships was 17 times as large and that of aircraft more than 20 times as large.

Railway equipment. In general, rails are made directly by the rolling mills connected with the larger steel plants and are included among the products of the iron and steel industry. This discussion, therefore, refers only to rolling stock, such as engines, tenders, cars, coaches, and accessories.

Railway equipment is manufactured by the countries which have both large steel industries and important home markets. Such countries are also in the most favorable situation to supply equipment to less-industrialized countries which have need for railway cars and locomotives. Thus the United States, England, and West Germany may export to such countries as Mexico, Ghana, and Uruguay.

Although railway repair shops are essentially service institutions, the larger ones carry on true manufacturing operations and are necessary factors in the success of any railway system. Repair shops, equipped and manned so as to be able to rebuild engines and rolling stock, must be part of the railway transportation industry whether the country be industrialized as highly as Belgium or as slightly as Paraguay.

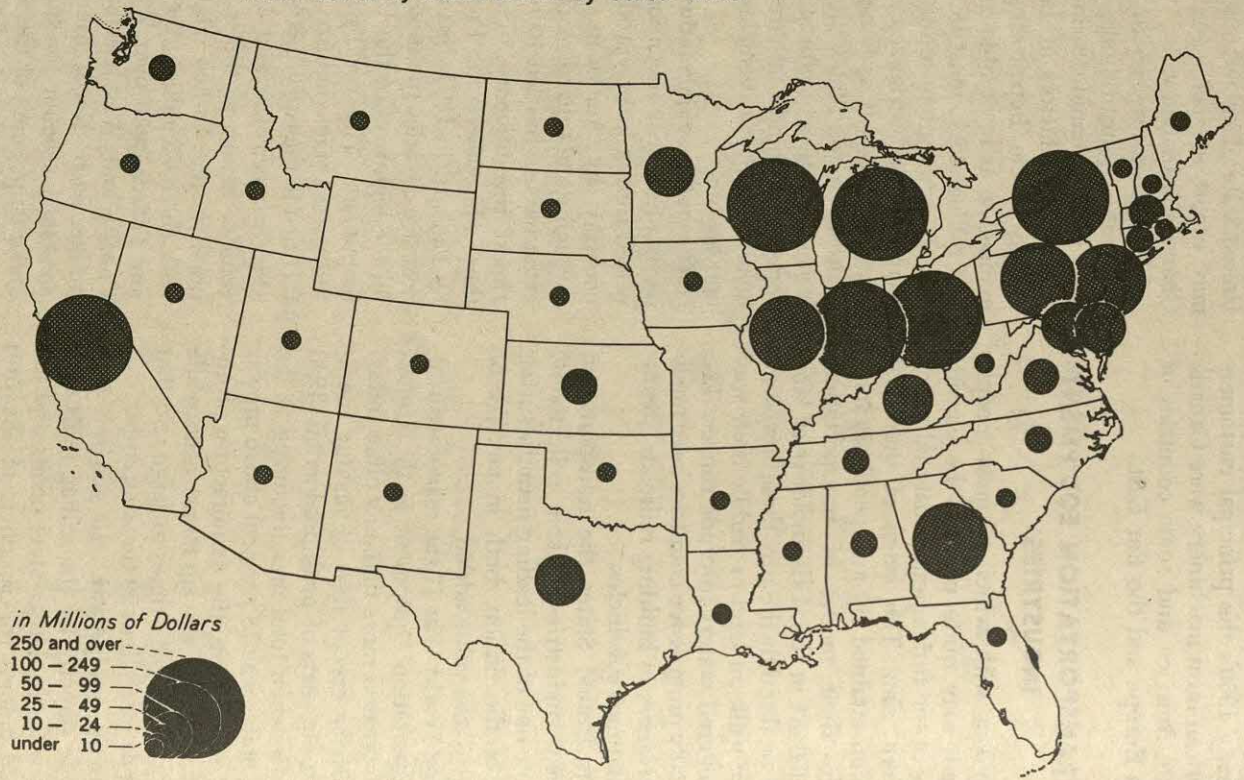
In the United States the value added by the manufacture of railroad equipment now comes far behind that added by the manufacture of motor vehicles, aircraft, ships, and boats.

The motor vehicle industry. The motor car is a European invention which was converted from a luxury product to a common necessity by American mass production through standardized machine methods. Its extensive use has led to results in industry almost revolutionary in scope. Little did those who viewed the French car designed by Panhard in 1894 dream that within the next five decades the motor industry would fill the highways of the United States with its products. The world-wide significance of the motor vehicle industry is reflected in the fact that in the early 1960's there were probably between 130 and 150 million motor vehicles in use in the world. Of the total number, the United States was credited with about 75 million; the United Kingdom and France, with over 7 million each; and Canada and West Germany, with over 5 million each. North America and Europe combined account for the manufacture of about 95 per cent of the world's motor cars —another illustration of the preponderance of these continents in the realm of manufacturing.

In the United States motor vehicle manufacture is of such significance that the industrial prosperity of the nation is insepa-

MOTOR VEHICLES AND MOTOR VEHICLE EQUIPMENT: SIC 371

Value Added by Manufacture by State: 1958



Bureau of the Census M-58-D371

Figure 363.

rably connected with it. The American people spend approximately one tenth of their national income for the purchase and operation of motor cars, this item exceeding every other class of merchandise except that of food and food products. The industry is of great importance to many others and consumes a great variety of basic items: mill shapes and forms of carbon steel, stainless and other alloy steel, copper and copper-base alloys, aluminum and aluminum-base alloys; copper and other wire and cable; castings, mostly of iron, steel, and aluminum; forgings; ball and roller bearings; coated fabrics; and a host of other materials and components. Every state in the Union and many foreign countries supply materials for this industry. The economic importance of the industry to farms, mines, factories, and labor cannot be overstated.

CENTERS OF AUTOMOBILE MANUFACTURING IN THE UNITED STATES. The earliest automobiles were popularly known as horseless carriages. Prior to the motor-car age, the most successful centers for the manufacture of wagons and buggies had developed in the eastern part of the great grain-growing belt, where raw materials of softwood, hardwood, iron and steel, power resources, labor, and markets in the fast-growing prairie farmlands were all at hand. Michigan, Wisconsin, Indiana, and Ohio had already developed prosperous wagon and carriage factories. When motors, particularly internal-combustion engines, were applied to locomotion it was natural that they should first be mounted on carriages, and it was equally natural that carriage makers and motor makers should combine their plants. Some of the well-known carriage makers who turned early to automobile manufacture were Haynes, Mitchell, Olds, and Studebaker. The centers of manufacture of autos, parts, and accessories remain in the states that were the leaders in the carriage industry.

The manufacture of motor cars thus is distinctly localized. In the early 1960's about 40 per cent of the total value added in the manufacture of motor vehicles and parts was in Michigan; Ohio was second, followed by Indiana, New York, Wisconsin, California, and other states. In recent years there has been a tendency toward the building of automobile assembly plants in cities in the West as well as in the East so as to save shipping space and reduce costs. (See Fig. 363).

TRENDS OF TRADE. The motor-car industry is essentially a development of the present century. The census reported only 4,192 cars and trucks made in the fiscal year ending June 30, 1900. At first, growth was slow; the annual output did not reach the 100,000 mark until 1909, and the 1,000,000 mark was first exceeded in 1916. Since 1922, in every year except 1932, 1933, and the four war years, the two million figure has been exceeded, and in 1929 production reached over five million motor vehicles, a figure not again approached until 25 years later when in 1955 more than eight million cars were produced. It seems clear that, although the period of rapid expansion may be over, the motor-car industry will continue to hold a position of front-rank importance in the economic life of the nation.

FOREIGN TRADE. Exports of motor vehicles from the United States have varied greatly. The drop in exports of American automobiles following the 1929 economic debacle was even greater than in many other lines. The people of importing countries still considered motor cars as luxuries; in periods of economic adversity, trade in luxury articles suffers more than trade in articles essential for carrying on the customary activities of life. In 1929 the total value of motor cars, parts, and accessories exported was 557 million dollars; in 1932, it dropped to 83 million. Recovery came in the later 1930's, and in 1947 peacetime exports for the first time passed the billion dollar mark. In 1944 war exports of motor vehicles for military use reached the fantastic total of 5,298 million dollars. Before World War II, the value of passenger-car exports was about twice as great as that of trucks. Since the war, truck exports have predominated. In 1954 the total value of American exports of motor cars, trucks, busses, trailers, parts, and accessories reached the astounding peacetime sum of 1,266 million dollars, but in recent

years totals have been between 500 and 600 million dollars. Exports are directed mostly to Canada and Latin America.

In other parts of the world also the motor-vehicle industry has grown in importance, especially after World War II. Originally many of the European manufacturers were noted for high-quality, almost individually assembled cars, but the American system of quantity manufacture has been adopted all over the world because the product is much cheaper, although the quality may be considerably lower than that of the almost indestructible European cars made earlier in the century. At present cars made in other countries are a common sight in American cities and on American highways.

The European Economic Community makes about half of the number of cars made in the United States and over half the number of trucks. The United Kingdom comes next with a production of about one fifth of the American number of cars and about three eighths of the trucks. Japan has a flourishing industry, manufacturing considerably more trucks than cars. Production of motor vehicles in Russia is expanding steadily, with also more emphasis on trucks than on passenger cars. Other producers of note are Canada and Australia.

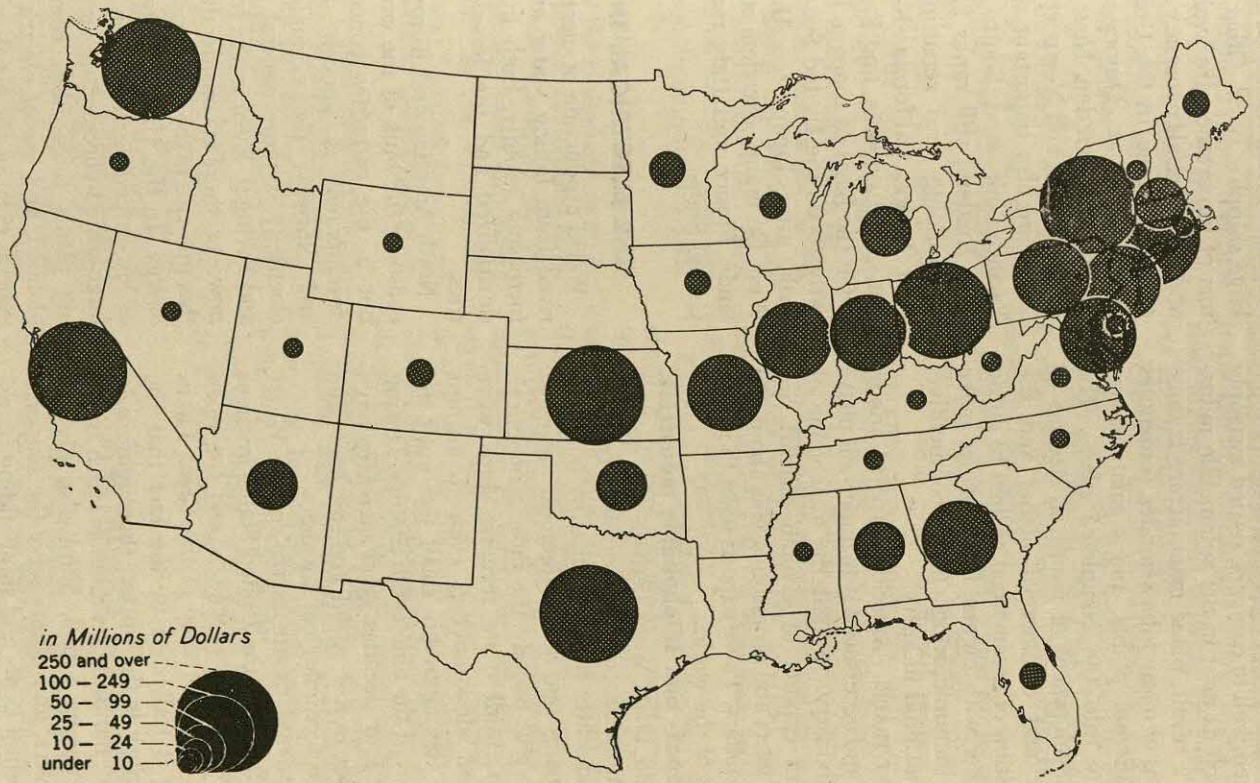
The aircraft industries in the United States. Since the first successful flight in a powered plane, made by Wilbur and Orville Wright in 1903, aircraft production has alternated between boom periods, occasioned by military demand, and relatively slack periods. The first commercial sale was made in 1909 by the Wright brothers to the United States Army. World War I became the first extensive proving ground, leading to important changes in aircraft design. After that war commercial use of the plane expanded until now most parts of the world are served by commercial lines. Aircraft have developed from the early wood-wire-and-cloth biplanes to the modern aluminum monoplanes, and the proportionate weight of aircraft engines has been reduced from nearly 16 pounds per horsepower for the Kitty Hawk to less than 1 pound per horsepower for modern planes. The efficiency of modern engines and aircraft has, of course, increased tremendously.

All modern industrial countries are engaged in aircraft manufacture, but in none has output been as great as in the United States. The number of wage earners engaged in the manufacture of aircraft and parts in the United States was 3,543 in 1919; 14,710 in 1929; and 62,000 in 1939. In 1940, just before World War II, President Franklin D. Roosevelt issued a call for an annual production of 50,000 planes, which then was considered an "impossible" figure. As the result of the war, by 1943 production-worker employment in the manufacture of aircraft and parts was 20 times that of 1939, and employment in production of aircraft motors was 26 times as large. In all, wartime production amounted to 300,000 planes. Though after the war production dropped far below its wartime peak, the production-worker index in the aircraft industry in the late 1940's was still three times as high as in 1939. The importance of the aircraft industries in our national economy is indicated by the steady increase in numbers of workers employed since the 1919 figure cited above. The average annual employment during the early 1960's has been between 700,000 and 750,000.

GEOGRAPHICAL DISTRIBUTION OF AIRCRAFT INDUSTRIES IN THE UNITED STATES The manufacture of aircraft and aircraft parts is widely distributed in the United States. Because it does not depend upon bulky raw materials, this latecomer on the industrial scene did not have to confine itself to existing industrial centers with their specific characteristics. Early aircraft centers were, it is true, in the industrial East, and even at the beginning of the great expansion in 1940 Baltimore and Buffalo still were major centers of the industry. Los Angeles and its satellite cities, however, had also become a leading center, favored by the mild weather that permitted flight testing of planes at all seasons. In the expansion associated with World War II, the government encouraged the establishment of new plants throughout the heart of the country, instead of along the more exposed coasts, and financed new

AIRCRAFT AND PARTS: SIC 372

Value Added by Manufacture by State: 1958



Bureau of the Census M-58-D372

Figure 364.

plants in such states as Texas and Kansas. Other important plants are in St. Louis, Seattle, and several smaller cities (Fig. 364).

The large size of modern planes does not lend itself well to compact, settled assembly lines such as exist in the automobile industry. As a result, plane manufacture is done by means of many subassemblies, sometimes from different plants, and a final master-assembly into the completed plane. The rapid development of improved designs of military and commercial planes and the competition of commercial airlines to outdo each other with bigger, faster planes make aircraft manufacturing a highly competitive, somewhat fluid industry.

EXPORT TRADE. American export trade in aircraft and accessories is an important phase of the industry. In 1961 the total value of American exports of civilian aircraft, including parts and accessories, was about 350 million dollars. These exports went to nearly all parts of the world.

The boat- and shipbuilding industries. Rafts and boats were perhaps the earliest vehicular means of transportation built by man, and water transportation by boat and ship remains one of the foremost means of haulage, and usually the most economical. However, until quite recently ships were small and slow-moving; even steamships were of comparatively small size until the latter part of the nineteenth century. During the past four decades great increases have been made in size, speed, and efficiency, due largely to technological advances.

SHIPBUILDING IN THE UNITED STATES. Water transportation in the United States involves lakes, rivers, coastal waters, and the open ocean. The importance of the Great Lakes shipping is indicated by the fact that the Detroit river is the busiest thoroughfare in the world, handling six times as much traffic as the Panama Canal. Ships also ply the larger rivers, and others serve the seaports. An important boat- and shipbuilding industry has developed to provide vessels and service docks for these transportation lines. Furthermore, pleasure boating is very popular in the United States, and a flourishing small-craft industry has developed in many parts of the country.

Since shipyards for building seagoing vessels must be located adjacent to deep water, they are generally constructed at or near large shipping ports. Other geographic factors of importance are availability of labor and the materials necessary for construction, especially steel. In the United States large centers are at Quincy, Massachusetts; Kearny and Camden, New Jersey; Chester, Pennsylvania, and Newport News, Virginia. There are also important shipyards on the Pacific, Gulf, and South Atlantic coasts. New England still ranks first in ship- and boatbuilding, and repairing, followed by New Jersey, California, New York, Louisiana, Pennsylvania, and Florida.

On the basis of tonnage launched, in the early 1960's the United States ranked about sixth, after Japan, the United Kingdom, West Germany, Sweden, and the Netherlands. France and Italy ranked below the United States.

THE ELECTRICAL INDUSTRIES

World production of electrical energy derived from falling water and from fuel is increasing rapidly, both in the highly industrialized and the less-developed countries.

North America and Europe produce and consume the bulk of the world's electricity, but in the countries concerned electrical development is uneven. In Switzerland and Norway, for example, the use of electricity is more general than in Poland and Portugal. Even in the former countries, however, there is considerable room for further increase in the consumption of electrical energy. In the United States, consumption of low-priced current is on the increase as large-scale hydroelectric and steam-generating plants have been completed, or are planned, and use of electricity has become general even in the rural areas.

In western and central Europe the hydroelectric industry has increased substantially above prewar levels. In eastern Europe the huge, industrially developing Soviet Union

is vigorously expanding its output of electric power.

Geographical distribution. In response to this growing use of electricity, the electrical industry, which manufactures machinery and equipment ranging in size from the smallest appliances to the largest dynamos, has rapidly come to occupy a strategic position in the modern economic structure. In the United States this industry group embraces the manufacture of: (1) electrical transmission and distribution apparatus, such as transformers, generators, switchboard and welding apparatus; (2) electrical household appliances; (3) electric lighting and wiring equipment; and (4) such items as storage batteries, X-ray apparatus, and others. The principal seats of the industry are found in the countries which have large consumption of electrical energy and at the same time possess highly specialized and well-established machinery industries. Other essential factors are, of course, capital resources and an adequate supply of skilled labor.

In quantity and value of products, the electrical industry of the United States ranks first by far and is followed at a considerable distance by that of West Germany and the United Kingdom. Among other producers should be mentioned Canada, France, the Netherlands, Italy, and Sweden. Japan and the Soviet Union have also made rapid progress in this field.

Electricity was first used on a large scale in the great city centers, and they have remained the principal markets for electrical goods. Thus the electrical industries have tended to develop near large cities.

THE UNITED STATES. In the United States the principal manufacturing centers are located in the so-called manufacturing belt. The New York-New Jersey industrial area leads all others in the production of electrical machinery, apparatus, and supplies. Other important states are Pennsylvania (Philadelphia and Pittsburgh), Ohio (Cleveland, Youngstown, and Toledo), and Massachusetts (Boston). California and upstate New York (Schenectady) should also be mentioned. Research laboratories—such as those established at Schenectady, Pittsburgh, Cleveland, and elsewhere—have been highly effective in promoting the development of the electrical industry. Their discoveries have led to the widespread use of new and improved appliances which have made possible higher standards of living for consumers and producers alike.

EUROPE. The electrical industries are well developed in all the leading countries of Europe, notably in the United Kingdom, France, West Germany, the Netherlands, Sweden, and Italy.

England is particularly noted for its manufactures of cables and heavy electrical apparatus. Among the principal centers are the Birmingham, Manchester, and London industrial areas, where power, labor, and markets are all readily available. The Netherlands and Sweden have become important producers of household electrical equipment, light bulbs, radios, television sets, and telephone supplies.

Exports of electrical products. As a result of the progress of electrification, even in relatively remote parts of the world—such as Australia, New Zealand, and Argentina—the international trade in machinery and equipment needed for the production and consumption of electricity has greatly increased in importance. The principal producers are also the principal exporters—the United States, France, and the United Kingdom. The exports of the United States are shipped largely to Canada and to Latin America, with the European market, however, not far behind. West Germany and France have their principal markets on the continent, while most of the British exports go to other parts of the world.

THE ELECTRONICS INDUSTRIES

As has been discussed elsewhere in this and in previous chapters, changes take place much more rapidly in modern industry than in most forms of agricultural activity. Even important new industries may arise within a comparatively brief span of time. An outstanding example of a new industry that has

grown at an astonishing rate is the electronics industry.

Radio and television sets, high-fidelity equipment, data-processing equipment, automated industrial machinery, and electronically controlled weapons are all quite new and are all either wholly or partly "electronic." An electronic product is one in which there is a variable and controlled flow of electrons and which uses the ability of that flow for signaling or information-carrying purposes. A television or other type of vacuum tube is an example. Thus "electronic" is different from "electric," and it is possible to separate the electronics industry from the electrical industry, which manufactures such items as transformers, electric motors, switchgear and switchboard apparatus, electric household appliances, electric bulbs, etc. However, it must be kept in mind that many firms and even some plants may manufacture both types of products.

Within the electronics industry there is a wide range of products from entire systems for communication, data-handling, or navigation purposes to equipment such as receivers, transmitters, amplifiers, computers, or radar devices to the small items which, as components, enter into the make-up of equipment and systems. Examples of such components are transistors, electron tubes, capacitors, and resistors. There is also a wide range in size of product, from very tiny components to such huge items as a radio telescope 600 feet in diameter. There are also great differences in the size of manufacturing concerns and plants, from the large firms that make television and radio sets to a partnership located in a tiny building and engaged in the experimental development of some highly specialized gear.

In the United States the electronics industry has grown until it now ranks among the top industries of the nation. Although precise figures are not available, there may be a total of about 4,000 plants, large and small, with perhaps 900,000 to 1,000,000 workers. In 1939 it was estimated that the number of workers in this industry totaled not more than 80,000.

Electronic plants may work for the industrial market, the military market, or the consumers' market. The manufacture for the consumers' market of such electronic products as television and radio sets is now dominated by a comparatively few large corporations. This, however, is not the case for the other segments of the industry.

Both the electrical and the electronics industries (the latter an outgrowth of the former) had their start in what is now the New York metropolitan area, but have since spread to other parts of the country. The greatest concentration of electronics plants is still found in the area of large urban agglomerations that stretches from north of Boston via New York to the Washington metropolitan region. Other important areas of concentration are the Chicago-Milwaukee, Los Angeles, and San Francisco regions.

About half of the electronics plants make various types of equipment; one fifth make systems; another fifth, components; the remaining 10 per cent falling into a miscellaneous group.

Why are these plants located where they are? Electronics plants should, of course, have easy access to good transportation facilities, but the industry is so specialized and so highly technical that transportation cost of heavy raw or semi-manufactured materials is but a small factor in final cost. Many of the components that the industry uses are comparatively small and of high value, and thus cost of transportation is not of primary importance. However, plants often depend on other electronics plants for purchase or sale of various items. Thus proximity of different types of electronics plants brings with it certain economies and conveniences, and this constitutes an important locational factor which favors concentration in specific areas such as those mentioned above.

In recent years there has developed a tendency toward a measure of decentralization. This is partly due to some advantages which result from a location close to industrial or governmental end-users of the products. Examples of such end-users are aircraft manufacturing plants and missile plants. Since much scientific research enters into the manufacture of electronic items, a rather novel locational factor is ready availability

of scientists and young graduates. Areas where there are outstanding universities or important government or private research centers have thus become attractive to electronics firms, especially to those that attempt to develop new items.

Although the industry is still growing, and some changes can be expected to occur, it does not seem likely that there will be any far-reaching changes soon in the major aspects of the present distributional pattern of the electronics industry.

SELECTED GENERAL REFERENCES

For detailed data on manufacturing in the United States, see United States Census of Manufactures, United States Department of Commerce, Bureau of the Census. Usually two volumes deal with industries in general, and one with industries by state. The census is usually taken every five years. Data are available more quickly as separates; there is some delay (one to two years) on publication as volumes. For other parts of the world see: *Statistical Yearbook,* United Nations, New York, annual. Also published by the United Nations are annual economic surveys of Europe, Latin America, and "Asia and the Far East."

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29

Industrial Regions

their development and location

BEFORE THE invention of modern power-driven machinery, when small-scale industry conducted on a handicraft basis was the rule, manufacturing could be carried on profitably even in small communities, as long as raw materials were available locally or could be brought in from nearby. Industrial establishments, if one could call them such, were highly scattered, perhaps with only some concentration here and there in port cities, important market towns, or areas that happened to be favorably located for certain types of enterprise; Flanders, for example, became noted in the Middle Ages for its manufacture (by means of hand looms, of course) of woolen goods. Where small water mills came into use for operating simple machinery, as in New England, parts of western Germany, and elsewhere, suitable sites were small, and enterprises remained fairly scattered. Only with the advent of coal as the chief source of power did areas develop where industry dominated economic activity to such an extent that it became possible to speak of manufacturing regions.

As the power-machine economy evolved, manufacturing in many countries became a major, or even the most important, economic activity, and industrial regions and districts increased both in number and areal extent.

TABLE (A)

PER CENT OF MANUFACTURING EMPLOYMENT FOR SELECTED COUNTRIES

Per cent of All Persons Employed, Including Agriculture.

Country	Year	Percentage
West Germany	1960	43.4
United Kingdom	1960	37.5
Belgium	1960	34.6
Canada	1960	24.6
United States	1960	24.5
Japan	1960	20.3
Philippines	1960	12.1
Nigeria	1959	6.7

SOURCE: *Yearbook of Labour Statistics, 1961.* International Labour Office, Geneva, Switzerland.

The percentages of the "gainfully employed" population engaged in manufacturing in many countries now exceeds that in other economic activities, and so does the contribution made by manufacturing to the national income.

Table (A) gives manufacturing employment by percentages for selected countries, and Table (B) the per cent of the gross domestic product derived from manufacturing in various countries. Table (C) shows the percentage of the national income of the United States derived from manufacturing as opposed to other sources of income for 1940, 1950, and 1960.

TABLE (B)

PER CENT OF GROSS DOMESTIC PRODUCT DERIVED FROM MANUFACTURING

Country	Year	Percentage
West Germany	1960	52
Netherlands	1960	42
United Kingdom	1960	37
France	1960	37
United States	1960	*30*
Japan	1960	30
Canada	1960	26
India	1959	17
Egypt	1956	12

SOURCE: *Statistical Yearbook*, United Nations, 1961.

TABLE (C)

PER CENT OF NATIONAL INCOME OF THE UNITED STATES BY ORIGIN

	1940	1950	1960
Manufacturing	*27.4%*	*31.0%*	*29.1%*
Wholesale and retail trade	17.6	18.1	16.5
Government and government enterprises—federal, state, and local	10.7	9.8	12.6
Services, total	10.8	9.5	12.1
Finance, insurance, and real estate	10.1	8.6	10.2
Contract construction	3.2	4.8	5.4
Transportation, total	6.2	5.6	4.3
Communications and public utilities	3.8	3.0	4.1
Agriculture, farms	7.4	7.0	3.9
Mining, inclusive of coal, petroleum, and natural gas	2.3	2.1	1.3
From rest of the world	0.5	0.5	0.5

SOURCE: *Statistical Abstract of the United States*, Bureau of the Census of the United States, pertinent years.

In view of the importance of the manufacturing industry in the present-day world, geographic questions such as the following are of interest: What differences are there in the locations of different types of industries? Why are there such differences? To what extent do geographic factors enter into the localization of industries? Are any changes occurring in the location of industries? If so, why? Where are the principal manufacturing areas of the world located? Why did they develop in these places? Within the scope of this book it is not possible to enter into these questions deeply. Such is generally done in separate treatises dealing with the geography of manufacturing. A few aspects of the first four questions have been touched upon in previous chapters. In this chapter the emphasis will be upon the last two questions.

THE BASES OF WORLD INDUSTRIAL LOCATION

A glance at Figs. 366 and 367, even though these maps, on account of their small scale, can show industrial regions only in generalized form and with omission of a host of small industrial districts, reveals at once the uneven and spotlike distribution of such regions. The distribution pattern is, however, an orderly one and has not developed haphazardly as might appear at first glance. A reference to maps showing, for example, distribution of population and of coal indicates that manufacturing often has regional relationships with natural resources (see Figs, 10, 240, 253).

Factors favoring concentration of manufacturing. Modern manufacturing must have access to raw materials, sources of mechanical power, machinery, and a labor supply. It must also have a market in which the final product can be consumed. The choice of localities for the establishment of manufacturing centers is less restricted than the choice of areas from which

to obtain raw materials. Coal is where you find it, and cotton is produced only in areas with climates favorable to its growth and harvest, whereas modern transportation and a degree of mobility of power permit factories to be established in a wide choice of localities. The determining factor may be the desirability to strike a balance between the costs of hauling the raw materials and supplies of power on the one hand and the cost of hauling the manufactured products to market on the other.

Often nearness to market is all-important because of the necessity of keeping in close touch with changes in customers' demands. Sometimes availability of capital in an area may be of prime importance. And there are many instances where choice of a region for establishing a plant may largely be the result of the predilections of an owner. However, regardless of what the causes may be, there is a definite tendency for industrial activities to tend to group together rather than to disperse. This may lead to the development of industry in separate large urban agglomerations, and even to the development of industrial regions where industry is so important that the cultural landscape is dominated by it rather than by agricultural or other activities which usually have a more areal character.

The modern industrial regions of the world have grown up: (1) where coal and, more recently, hydroelectric power or petroleum are available; (2) where raw materials are produced; (3) in or near large centers of population where there is an abundant labor supply and a good market of consumers; and (4) at good trading locations such as port cities, to which both materials and labor can be brought at reasonable expense and from which the finished products can readily be shipped to wider markets. Obviously these factors are interrelated, and in a given manufacturing district two or more of them are commonly important. In general, the factor of finance capital plays a minor role in the location of industry, as finance capital normally flows easily to points where safe maximum profits are anticipated.

The geographical distribution of population, agricultural and forest raw materials, and power and mineral resources, as well as certain related major industries, have been discussed successively in preceding chapters. It remains to be shown how these natural resources, human resources, and economic activities frequently focus so as to develop manufacturing regions. In no phase of geography is the interdependence of all regions—rural, mineral, and urban—more clearly visible than in manufacturing.

Industrial concentration near coal fields. Early in the Industrial Revolution a large and cheap supply of power became necessary for any important industrial development by means of the steam engine. Such a supply was found in coal fields: Coal can be used to generate steam power from water to turn machinery, as in the textile industry, but also for direct treatment of raw materials, as in the smelting of iron ore. As coal is a bulky material of relatively low value, it cannot be transported over long distances, except by water, without incurring high freight charges and thus becoming too expensive for large manufacturing industries. Heavy industries, which are large consumers of coal, therefore early began to congregate in or near coal fields.

Thus, from the beginning of modern industrialization certain types of manufacturing industries have grown up close to coal mines. Among these, the iron and steel industry ranks first. The larger the furnaces and steel mills grow, the more they become dependent upon a cheap supply of coal as a source of both fuel and power. Originally, nearly two tons of coal were needed—partly reduced to coke—to recover the iron (as pig iron) from one ton of ore. Consequently, where iron ore was not available in close proximity to the coal fields, it was cheaper to ship the ore to the coal rather than to ship the coal to the ore. At present, as a result of technical progress, much less coal is needed for smelting. However, pig iron is only a semifinished product and must be made into cast iron, wrought iron, or steel through further processes of manufacture, all of which require substantial amounts of additional fuel and power. Furthermore, the steel billets must be fashioned into all kinds

of shapes for further use, which also requires additional fuel and power. Thus, although the iron and steel industry is not bound to coal as closely as it was in the past, it is still found primarily in fairly close association with coal fields.

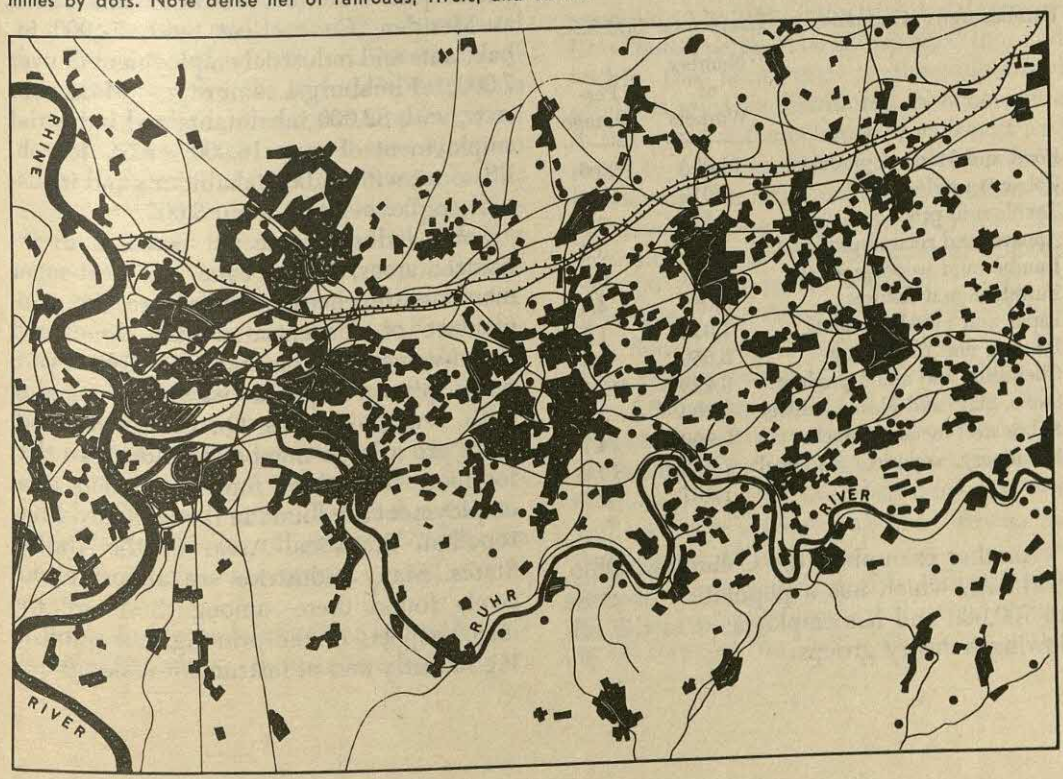
There are many other industries for which cheap fuel and power are essential and which therefore tend to congregate, in or not too far from important coal fields. Examples are the glass industry, the pottery industry, and those chemical industries which use coal tar (the tar residue which remains after the manufacture of coke) as a basic raw material.

Secondary coal-using industries tend to develop along the routes over which raw materials are transported to coal fields. Thus, ore boats carrying return cargoes of coal from the Appalachian field have favored the development of secondary industries along the Great Lakes.

Effects of other forms of power upon industrial concentration. The more recent and more easily distributable forms of power available to industry have until lately done relatively little to counteract the tendency of manufacturing industries to congregate. Originating mostly outside the established industrial districts, petroleum, fuel oil, gasoline, and natural gas have tended to flow to existing centers of manufacturing by means of cheap pipeline or tanker transportation rather than to attract industries themselves. However, while the better distributability of petroleum products, as well as of electric power, are helping to counteract an unwieldy degree of industrial concentration, it cannot be expected to cause a complete decentralization of manufacturing. Areas where power is available at low cost and where agglomerations of population constitute great markets will continue to be the most logical sites for many types of industry.

Industrial development near raw materials. Many specialized manufacturing industries have grown up near the sources of raw materials. In the food processing industries, for example, the raw materials are

Fig. 365. Ruhr district, a thickly settled industrial region. Built-up areas shown in black, coal mines by dots. Note dense net of railroads, rivers, and canals.



so perishable and so far superior when processed fresh that the canneries and other processing plants are built within easy hauling distance from farms or at fishing ports. Industries such as copper smelting or lumbering, which involve the handling of large weights of waste material in proportion to the processed product, also find it advantageous to save transportation bills by locating near the source.

Industrial development in and near population agglomerations. Large urban agglomerations, constituting important markets in themselves as well as being possible good source areas for labor, always tend to attract additional industries. Besides, such areas encourage the growth of consumer-goods industries by the very fact that the large population has large needs for food, clothing, and a multitude of other goods. Thus large urban areas often attract quite a number of different industries. The Louisville S.M.S.A. (Standard Metropolitan Statistical Area, which embraces Jefferson County, Kentucky, and Clark and Floyd counties, Indiana) has a population of over 600,000 and has employment in the following industry groups:

Employment Grouping in Louisville S.M.S.A.

	Number of Workers	Percentage
Food and kindred products	14,003	20.6
Tobacco products	8,013	11.2
Textile-mill products	573	0.9
Apparel and related products	2,318	3.5
Lumber and wood products	4,477	6.6
Furniture and fixtures	3,016	4.4
Paper and allied products	1,014	1.5
Printing and publishing	5,659	8.4
Chemicals and allied products	8,229	12.0
Stone, clay, and glass products	2,465	3.6
Fabricated metal products	9,969	14.7
Machinery, excluding electrical	7,423	10.9
Others	1,187	1.7

Another example is the Columbus, Ohio, S.M.S.A., which has a population of close to 700,000 and has employment in the following industry groups:

Employment Grouping in Columbus, S.M.S.A.

	Number of Workers	Percentage
Food and kindred products	8,917	13.4
Apparel and related products	615	0.9
Furniture and fixtures	924	1.4
Paper and allied products	1,298	1.9
Printing and publishing	4,811	7.2
Chemicals and allied products	2,535	3.8
Rubber and plastics products	1,125	1.7
Leather and leather products	1,955	2.9
Stone, clay, and glass products	3,465	5.2
Primary-metal industries	2,236	3.4
Fabricated metal products	9,424	14.2
Machinery, excluding electrical	9,911	14.9
Electrical machinery	5,191	7.8
Transportation equipment	11,546	17.4
Instruments	1,490	2.2
Others	1,098	1.7

Even comparatively small population agglomerations may be attractive to industry. In the United States the great majority of the industrial establishments are located in the so-called Standard Metropolitan Statistical Areas, of which New York has the largest population, nearly 11 million, but of which quite a number are rather small, such as Meriden, Connecticut, with 52,000 inhabitants and industrial employment of over 7,000; Fitchburg-Leominster, Massachusetts, with 82,000 inhabitants and industrial employment of over 16,000; or St. Joseph, Missouri, with 91,000 inhabitants and industrial employment of about 8,000.

Some industries are not common in urbanized areas, such as cane- and beet-sugar manufacture, cheese manufacture, the manufacture of concentrated milk, lime, and broad-woven cotton fabrics, cotton-yarn mills, plywood plants, sawmills, planing mills, and pulp mills. On the other hand, there are a large number of industries that for more than three fourths of their total employment are found in the Standard Metropolitan Statistical Areas in the United States. Many industries are almost exclusively found there; among these are the major aspects of the printing and publishing industry and of instrument making; cer-

tain aspects of the electrical industry, such as the making of telephone and telegraph equipment, X-ray apparatus, and electrical control devices; the aircraft and aircraft engine industries; and a number of others.

To save unnecessary crosshauling of the finished product, many consumer industries tend to develop in market areas. Petroleum refining, for example, an industry that produces its own fuel, is extensively developed not only near Texas, Louisiana, and California oil fields but also near the big population centers of eastern United States.

Industrial development in port cities. Port cities frequently have no significant local resources either of fuel or raw materials, but are favored by excellent transportation facilities, by sea, by rail, and, frequently, by inland waters. New York is an example of a port city with excellent railroad connections, Rotterdam of a port city with both excellent inland waterways (Rhine, Meuse, and a number of other important waterways) and good rail connections. Port cities such as London, Buenos Aires, and San Francisco are similar to the first case, while Shanghai, Montreal, and Hamburg are more similar to the second. In all cases, favorable location for the assembly of raw materials and semifinished goods and for the disposal of the end products of manufacture, plus the industrial attraction always exercised by a great concentration of population, have made these cities into major industrial and trade centers. In the New York S.M.S.A. (New York City, plus Nassau, Suffolk, Rockland, and Westchester counties, New York) with a population of nearly 11 million, over one million are employed in industry; in the San Francisco-Oakland S.M.S.A. (San Francisco, Alameda, Contra Costa, Marin, San Mateo, and Solano counties) with a population close to 3 million, about 180,000 persons are engaged in industry; in the New Orleans S.M.S.A. (Orleans, Jefferson, and St. Bernard parishes), with a population of about 850,000, the number of persons engaged in industry is 45,000.

Effect of industrialization upon the cultural landscape. Industrialization has far-reaching effects upon the distribution of the population and upon the appearance of the cultural landscape. It fosters the growth of industrial nuclei, leaving areas of relatively sparse population between. In New England, for example, extremely dense population in the industrial cities and valleys occurs next to sparse population in adjacent upland areas. Agriculture may suffer from the loss of labor, owing to the greater remuneration offered by work in the nearby industrial centers. To feed the cities, however, dairying and truck farming may develop in an extensive surrounding zone.

In some of the more extreme cases an entire region may become urbanized. Mine hoists, culm piles, factory buildings, innumerable smokestacks, row upon row of dreary tenement houses or workers' cottages, and vast railroad yards with miles of track all but obliterate the natural landscape (Fig. 365). Such conditions are found in the Ruhr region of Germany, the so-called Black Country near Birmingham, England, and other areas.

The transportation network is strikingly affected by industrialization. The growth of manufacturing is accompanied by improvement of the means of transportation, so essential to modern industrial development. Raw materials must be transported into and within the area, and semimanufactured products must be distributed. Nowhere else in the world is the network of railroads and roads so dense and so intricately woven as in some of the large industrial districts. In the lower Rhine region of Germany, for example, there are over 25 miles of railroad per 100 square miles, while in highly industrialized and densely populated Belgium this figure rises to over 55 miles. In the Ruhr region, adjoining the Rhine, there are over 3,000 miles of railroad track (Fig. 365). Where water transportation is available, as in northern France, Belgium, and the Netherlands, it is often used for short hauls as well as for relatively long ones. Rivers are deepened and regulated, and canals are built. The principal British industrial regions all have easy access to the tidal waters, while those of the United States are within

easy reach of the Atlantic (including the Gulf of Mexico), the Pacific, or the Great Lakes waterway. In recent decades the network of roads has been greatly improved in most of the important industrial regions as a response to the rapid increase in the use of trucks as freight carriers and as links between rail or water and factory.

THE PRINCIPAL INDUSTRIAL REGIONS OF THE WORLD

The result of the interplay of the factors just discussed has been the development of the world's great industrial regions. The main diversified heavy-industry regions are in the northeastern quarter of the United States, in northwestern Europe, and in the Soviet Union (Figs. 366, 367).

Industrial regions of northeastern United States. In the United States a highly industrialized and densely populated section stretches inland as a relatively narrow discontinuous belt from the Atlantic coast between Boston and Baltimore to a line drawn from Cincinnati through Indianapolis and Peoria to a point somewhat north and west of Milwaukee and including southern Ontario. The states included have about one half the population and a little more than half the income of the United States, but they have over two thirds of all manufacturing employment, four fifths of the iron and steel manufacturing, nine tenths of the automobile manufacturing, four fifths of the apparel manufacturing, and two thirds of the chemical industry. Within this section of North America several individual industrial regions can be recognized. (See also Fig. 373.)

THE PITTSBURGH-WHEELING-CLEVELAND REGION. The Pittsburgh-Wheeling-Cleveland region is closely associated with the northern Appalachian coal fields. The presence of high-quality coking coal has fostered the development of an extensive iron and steel industry which is able to import iron ores cheaply via the Great Lakes waterway. While the manufacture of iron and steel dominates, especially in the Pittsburgh and Youngstown areas, numerous associated steel-fabricating industries have developed. The Pittsburgh area also has an important glass industry. Akron is the largest rubber manufacturing center of the world, and half of the workers employed in the area are engaged in the rubber industry. East Liverpool is noted for its manufacture of pottery.

THE NEW YORK-PHILADELPHIA-BALTIMORE REGION. The New York-Philadelphia-Baltimore region, the most densely populated part of the United States, includes, besides the metropolitan areas of the cities mentioned, most of northern New Jersey and a considerable portion of eastern Pennsylvania. The entire region is within easy reach of the northern Appalachian coal fields; it has port facilities that permit importation of raw materials and export of the finished products not absorbed within the region itself; and it has a large internal market. Industry is highly diversified, and both the total value of the products and the number of people employed exceed those of any other industrial region. About two thirds of the national employment in the clothing industry is here.

In the Baltimore area industries producing primary metals, transportation equipment, apparel, electrical machinery, and fabricated metal products are most important. The Philadelphia area manufactures especially apparel, fabricated metal products, nonelectrical and electrical machinery, primary metal products, textiles, and chemical products, and it has an important publishing industry. Iron, steel, foundry products, machinery, textiles, apparel, cement, and leather are important manufactures in other centers of eastern Pennsylvania. Among the principal industries of New Jersey are the manufacture of electrical machinery, chemicals, apparel, fabricated metal products, transportation equipment, primary metals, and textiles. Diversification of industry is greatest in the New York City area; among the innumerable industries, apparel manufacture stands out as employing exceptionally large numbers of workers. Other important industries are printing and publishing, the manufacture of electrical apparatus, chemicals, fabricated metal products, transportation equipment, knit goods and other textiles, and instruments.

THE SOUTHERN NEW ENGLAND REGION. The early development of the textile industries of southern New England was due mainly to the availability of cheap water power. Coal was later imported from the nearby Appalachian region either by rail or by means of coastal navigation. At present, as in most industrial districts in the United States, the energy used in the factories is mainly in the form of electrical current derived either from coal or water power. In the past the textile industries were important in the economic life of the region, but they now play a subordinate role. The shoe industry, though still important, has also suffered from the competition of factories located farther west, closer to sources of raw materials. New England industry is now highly diversified. Among the large number of industries represented in New England, some well-known specialties are the brass, electroplating, and firearms industries in Connecticut, the jewelry industry of Rhode Island, and the manufacture of paper in the Connecticut Valley of western Massachusetts and in southern New Hampshire.

THE DETROIT REGION. The Detroit region, which includes also the cities of Lansing, Flint, Pontiac, and Jackson, specializes in the manufacture of motor vehicles. Directly or indirectly associated with this industry are important iron and steel, foundry, machine-tool, wire, and paint industries. The Detroit river, a strategic link in the Great Lakes waterways, is one of the busiest stretches of water in the world. Its flow of raw materials can be tapped by the Detroit automobile manufactures. Immediately to the west lies one of the important furniture-manufacturing areas of the United States, that of Grand Rapids, based in part upon an original source of hardwood and in part upon the household needs of the new midwestern population.

THE SOUTHERN LAKE MICHIGAN REGION. The southern Lake Michigan region includes the Chicago area and parts of the neighboring states of Wisconsin and Indiana, with the cities of Milwaukee, Gary, and South Bend. Because of its large market area and its easy access to the iron ore of the upper Great Lakes district and Labrador, and the coking coal of the northern Appalachian field, this region is able to support a flourishing iron and steel industry. Other industries of the region are the manufacture of electrical and nonelectrical machinery, fabricated metal products, transportation equipment, chemicals, and apparel. Printing and publishing are also important. Because of an extensive agricultural hinterland with which it has excellent communications, Chicago has become a major meat-packing center in the United States.

OTHER REGIONS. Among other important manufacturing regions within the northeastern industrialized belt are the upstate New York region of diversified manufactures from Buffalo and Niagara Falls to Troy; the Cincinnati-Dayton-Columbus region of southwestern Ohio; and the Indianapolis district.

Industry in the South and West. World War I and World War II were both accompanied by large increases in the manufacturing industries of the United States. In the course of the second war, construction of new plants totaled about 10 billion dollars, and postwar construction has added many more billion dollars to this figure. Though all parts of the country shared in this increase, the rate of growth of manufacturing has been far greater in the South and the West than in the older industrial regions of the Northeast.

These regional changes began even before World War II. They were, however, accelerated by the wartime desire to decentralize certain industries for greater security against attack, to save transportation space by producing consumer goods locally, to utilize local resources more fully, and to promote a better-balanced economy for the country as a whole. Government prewar action in providing large new sources of hydroelectric power on the Tennessee, Colorado, Sacramento, and Columbia rivers stimulated industrial development in the South and the West. During the postwar period, the continuation of hydroelectric development and the reduction of freight differentials between the East and the other parts of the country have further encouraged the trend. Population growth, especially in the Far West,

provides a growing labor supply and consumer market. Finally, development and expansion of any industry in a region results in higher income for that region, followed by additional migration of people to the area, which in turn provides the basis for new and expanded consumer-goods industries. The expansion cycle, once underway, is self-feeding for a considerable period of time, and the industrial trend toward the South and the West at present shows no signs of over-all slackening.

INDUSTRIES IN SOUTHERN UNITED STATES. Industrial development in southern United States, from Virginia to Texas, has made consistent but uneven progress since the 1920's. Leading manufactures are devoted to processing raw materials produced within or near the region, such as cotton, wood, tobacco, petroleum, and sulfur.

The cotton-textile industry centers on the Piedmont, from southern Virginia through North Carolina to and including the upper Piedmont of South Carolina. In this area there is also manufacture of fabrics from synthetic fibers, and there are woolen and knitting industries. Some apparel is also made in the area, and there are furniture and tobacco manufactures. The industries are located in the cities and small towns, and although the landscape remains essentially an agrarian one, this area can be considered an industrial region because industry is by far the most important economic activity. Elsewhere in the South industry is largely located in more or less separate urban areas, the most important of which could be referred to as industrial districts.

One such is the Birmingham, Alabama, district. Here the manufacture of iron, steel, fabricated metal products, and transportation equipment are important. The juxtaposition of coking coal, iron ore, and limestone for flux has created one of the country's best natural sites for the steel industry. Compared with the industrial Northeast, Birmingham has a freight advantage for supplying much of southern United States with iron and steel products.

The lumber and related industries of the South find their raw materials in the pines of the Coastal Plain and the hardwoods of the Piedmont and the southern Appalachians. Petroleum industries are based primarily on the nearby oil and gas fields. Aircraft and parts industries in Texas and Georgia and shipbuilding in Mobile and other Gulf ports are examples of industries established as part of wartime expansion and decentralization programs.

Most of the lesser industries of the South have been growing proportionately faster than the industries in the Northeast. Some of these industries are related to local raw materials; for example, the sulfur industry of Texas furnishes a basic raw material to the manufacture of paper, various chemicals, and synthetic rubber in the general area. Others, such as furniture and printing, are stimulated not only by the presence of raw or semifinished materials but also by the existence of a consumer market heretofore depending upon "imports" from the Northeast. The cheap power made available by the Tennessee Valley Authority has favored the establishment of aluminum and other industries. Examples of other industrial districts in the South are Houston, Texas, with especially metal, machinery, petroleum, and chemical industries; Atlanta, Georgia, which is quite highly diversified industrially, but with food products, apparel, and textile products occupying first rank; and Mobile, Alabama, where the manufacture of paper and allied products, lumber and wood products, chemicals, and transportation equipment (ships) are most important.

Industries in the Midwest. The midwestern farm states of the Minnesota-Montana-Colorado-Missouri quadrangle, after lagging behind the rest of the country in industrial development, have shown gains in regional percentage of output in a number of fields of industry since 1940. Food processing remains by far the major industry of this region, based primarily upon the abundant production of wheat and beef. Along the eastern side of the region the great food-processing centers of Minneapolis-St. Paul, Omaha, Kansas City, and St. Louis have acquired other industries as well, and smaller cities also have developed industrially in recent years. The St. Louis in-

dustrial district, which embraces adjacent counties in Illinois, has the advantage of an exceptionally central position for rail, water, and air transport, as well as power resources within easy reach. It has developed important industries manufacturing transportation equipment, machinery, primary metal products, fabricated metal products, chemicals, apparel, and leather. However, food industries still employ about one eighth of all industrial workers.

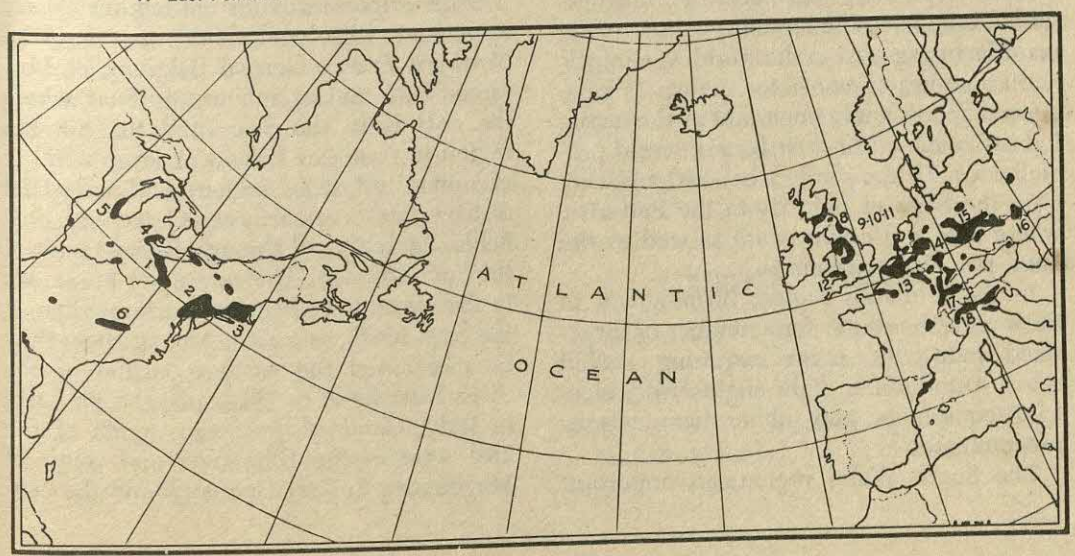
The Far West. The most striking population gains in the United States in the years after 1940 have been made in the Far West. The increased population provided an increased labor supply and consumer market and helped to stimulate the already greater-than-average rate of increase of manufacturing. In all major census categories of industries, except lumber, employment in the early 1960's was greater than in 1939.

Two major industries, food and lumber, illustrate the same dependence upon local raw materials as is shown by industries in the South. The food comes largely from orchards and commercial truck farms of the California and Oregon lowlands and from the ranches and grain lands of the coastal states, supplemented by the meat and wheat of the interior. The lumber is provided by the forested mountain slopes from central California to Canada.

Important is the manufacture of transportation equipment, chiefly airplanes, which grew before, during, and after the war in the Los Angeles and San Diego areas of southern California and elsewhere, partly as a result of the favorable climate. Wartime-established shipbuilding in Portland and Seattle and chemical and aluminum industries of the Seattle area and hinterland, aided by the Bonneville, Grand Coulee, and other power developments, are among important new or expanded industries. In textiles, apparel, printing, and other consumer-goods industries, as well as in iron, steel, and ma-

Fig. 366. Principal industrial districts of eastern United States and western Europe.

1. Pittsburgh-Wheeling-Cleveland
2. New York-Philadelphia-Baltimore
3. Southern New England
4. Detroit
5. Southern Lake Michigan
6. Southern Piedmont
7. Scottish Lowland
8. Newcastle
9. East Pennine
10. Midlands
11. Lancashire
12. South Wales
13. Northern France-Belgium
14. Ruhr
15. Saxony-Bohemia
16. Silesia
17. Swiss Plateau
18. Northern Italy



chinery production, the West is attempting more and more to meet its own requirements instead of depending upon products freighted in from eastern United States.

Industrial regions of Europe. In Europe industrial development is greatest in a belt that stretches from the British Isles through northern France, Belgium, Germany, Poland, and Czechoslovakia into southern Russia. The major industrial regions, with the exception of that of London, all lie on or near important coal fields (Figs. 366, 251).

GREAT BRITAIN. In the Scottish lowland region industry is concentrated around Glasgow. Coal and tidewater transportation have long been important in the development of a variety of industries, including shipbuilding, light and heavy engineering, various textile products, and, increasingly, consumer goods.

The Newcastle region, with its coastal location and coal supply, supports a highly developed shipbuilding and associated marine-engineering industry. Chemicals, using local salt deposits, and heavy machinery are also manufactured.

On either side of the Pennines the coal fields have led to large industrial concentrations. On the east, woolen textiles are a specialty around Leeds, and farther south Sheffield is important for the processing and working of special and alloy steels and the manufacture of tools and cutlery. In the Lancashire region, west of the Pennines, the densely populated area north of Manchester has long been the foremost cotton-textile manufacturing area in the world. Chemicals and a number of associated industries have become increasingly important as the textile industries have lost their former world-preeminence. To the south, local coal and clay form the basis of industry in the Potteries, where tiles and earthenware as well as the finest porcelains are made.

In the Midlands region, Birmingham in the west is the center for a number of diversified industries, many requiring skilled labor. Automobiles, light engineering, electrical equipment, and rubber manufactures predominate.

The South Wales region, an important producer of iron and steel, is also the center of the tinplating and of nonferrous smelting and refining industries.

The London region, with its large labor force and market and transportation facilities, has a wide variety of industries, but concentrates particularly on the manufacture of consumer goods and on the processing industries.

Continental regions. On the European continent the Ruhr and Lower Rhine regions of Germany stand out as highly industrialized areas. Within a territory of less than 110 miles from northeast to southwest and 40 miles from northwest to southeast lie more than a dozen cities with populations varying from 100,000 to over 500,000, besides a host of smaller ones. The coal, iron, and steel of the Ruhr normally lead Europe in production in peacetime, and in wartime they provided the equipment with which the Nazis overran most of the continent. Little wonder that the problem of how to use the Ruhr to promote European prosperity while preventing its use for a third time as an arsenal was one of the knottiest and most-discussed questions of Europe, a question which undoubtedly contributed greatly to the creation of the European Coal and Steel Community, the forerunner of the European Economic Community. This district manufactures all kinds of metal products, from the heaviest machinery to knives and needles. Textile and chemical manufacture are also important (Fig. 365).

Other important industrial regions closely associated with coal fields are those of Northern France-Central Belgium; of Lorraine-Southern Luxembourg-the Saar, where the coal is in the Saar; and the Silesian region in southern Poland. A large number of minor industrial regions and industrial districts, not necessarily associated with coal fields, are scattered through Europe west of the Soviet Union. They are more numerous in the western and central portions than in the east, north, or south. Among them may be mentioned the eastern portion of the Swiss Mittelland or "Plateau"; the Po basin in Italy; Catalonia in Spain; much of the area west of the Elbe river and south of Magdeburg in East Germany; and the cen-

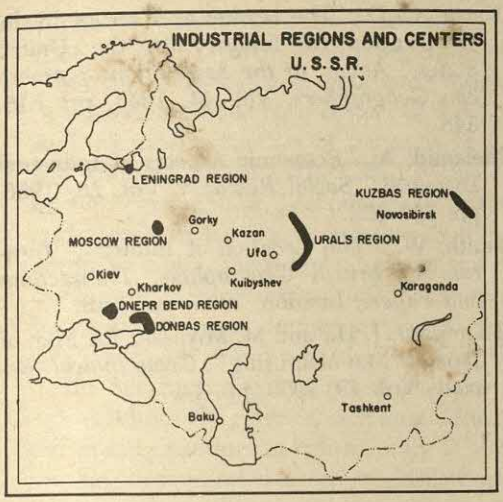


Figure 367.

tral part of the Bohemian basin in Czechoslovakia. The first two have access to water power and import coal; Catalonia ships in coal; and the last two have easy access to lignite and coal deposits respectively. The Paris and Berlin metropolitan areas are examples of major population centers that have also become important industrial districts.

In the Soviet Union two major industrial regions have developed in association with coal: the Donbas (Donets Basin) and the Kuzbas (Kuznetsk Basin). The former is based upon the Donets coal basin, one of the major European coal deposits and is located in southern Russia between the Sea of Azov and the Donets river, a tributary of the Don river. It is an area of heavy industries, chemical industries, and many others. Major cities among about a dozen are Rostov and Donetsk (formerly Stalino). The Kuzbas lies over 2,100 miles to the east northeast in Asiatic Russia, beyond the upper Ob river. It is also based upon one of the world's major coal basins and has much heavy industry. The German occupation of western European Russia, including the Donbas, furnished the impetus for major industrial development in this area.

The Dnepr Bend region lies in the great bend of the river of that name west of the Donbas. It has power from the great hydroelectric development near Dnepropetrovsk and includes the Krivoy-Rog iron-ore deposits. Metallurgical and electrochemical industries are important. The Urals region, from the city of Nizhniy Tagil in the north to Magnitogorsk in the south, is an area of production of iron, steel, nonferrous metals, and chemicals. The Moscow region includes a fairly large region around the Moscow metropolitan area and might be extended southward as far as Tula and northeastward as far as Ivanovo. Industries are highly diversified: machinery, chemicals, textiles, and many other consumer goods are included. Among the host of smaller industrial districts might be mentioned the Leningrad, Kiev, Gorkiy, Kharkov, and Baku districts.

Other important areas of industrial development in the world. In the Orient important industrial districts are the Kobe-Osaka, Nagoya, and Kwanto Plain districts of Japan; the Shenyang (Mukden) and Anshan districts in southern Manchuria; and the Shanghai and Hankow-Wuchang districts of central China. In India and Pakistan industry has developed in and near many large cities, such as Bombay, Calcutta, Cawnpore, and others, and with a main center of metal manufacture west of Calcutta. Industrial progress is made in other parts of the world: there are textile industries of considerable importance in the state of São Paulo, Brazil; petroleum refineries in Venezuela; and food and metal industries around the Río de la Plata. There is considerable industry especially in the Sydney and Melbourne districts of Australia, and industries are growing in importance in many other parts of Latin America, Africa, and Asia. However, Europe, including the Soviet Union, and Anglo-America remain dominant in manufacturing.

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30

Geographic Aspects of Transportation and Commerce

WITHOUT TRANSPORTATION, economic utilization of the earth would be completely impossible. Specialized economic pursuits discussed in preceding chapters of this book, such as the production of bananas in Central America, wheat in the Great Plains, coal in the Appalachians, and copper in Katanga and Northern Rhodesia, are due to the advantages which these areas have in the production of these commodities. There would be no point in producing surpluses of the specialties of any particular area if they could not be moved to other parts of the world where they are in demand. Man undertakes to produce surpluses only if he can market them in other areas, and this implies transportation. The modern world is characterized increasingly by a division of labor, in which not only different people but different areas or regions specialize in producing different things. Thus transportation is basic to specialization, the accumulation of surpluses, and their exchange.

Movement of people and goods requires time and energy to overcome the "friction" of the earth's surface, which is due in part to the pull of gravity. So great is the effort involved that from 10 to 20 per cent of all gainfully employed people are engaged in helping other people and goods to overcome the barriers of distance. The time needed, the energy consumed, and the cost of the vehicles, be it a camel or a modern freight train, must ultimately be paid for, and the world as a whole faces an annual transportation bill which runs into many billions of dollars. All of us pay a small portion of that bill every time we buy something, whether it be an imported novelty or a pound of coffee, a loaf of bread or a bottle of milk.

In order to understand some of the basic principles of transportation, we need to know how much it costs to overcome the earth's friction. One measure is the cost per ton-mile, i.e., the cost of moving a ton the distance of one mile. For this purpose we are really interested in average costs derived from many thousands of actual individual transport operations. Striking differences exist between the ton-mile average costs of different media of transport. Cost of modern

highway transport averages about 6 cents per ton-mile. The cost of railroad transport is less than 25 per cent as great as that of truck transport, the average being 1.4 cents per ton-mile. Most forms of water transport appear very cheap when contrasted with land transport. An oceangoing freighter has costs as low as 2 mills per ton-mile; river barges can move bulky freight at a cost of only about 4 mills per ton-mile, and the larger Great Lakes freighters achieve phenomenally low costs—down to a rock-bottom of 1 mill per ton-mile! Modern air transport is roughly about one hundred times as expensive as ocean transport, since its carrying costs average 21 cents per ton mile. The relative economy in transport costs, which comes from the use of "modern" forms of transport based on the use of inanimate energy, is readily seen when we begin to compare modern with primitive transport: a horse and wagon costs about 25 cents per ton-mile, and man, acting as human porter, does worst of all, piling up costs which may range anywhere from 25 cents to $1.00 per ton-mile!

Cost of transportation is, of course, not the only consideration in the choice of means of transportation; speed, convenience, and a host of other factors are involved and encourage the use of different types of transport for different purposes. By and large, however, the bulk of the world's freight moves toward its destination by the cheapest means of transport available.

In the economically advanced parts of the earth, such as Western Europe or the United States, an enormously complicated movement of goods is necessary to assemble the wide array of different commodities used or consumed at any one place. Interchange of goods between diverse regions results in traffic flows, which may be pictured as streams of goods moving along particular transport routes, such as a main railroad line. Some routes, because of the regions they interconnect or, in the case of land routes, because of their facilities or characteristics, may have a comparatively large volume of freight moving along them in the course of a year. Such routes may be said to carry a large flow of traffic. An outstanding feature of the world's transport routes is that comparatively few routes with large flows of traffic stand out from a far larger *number* of routes which have small or even insignificant traffic.

Whenever routes carry much traffic, whether they be sea lanes, railways, highways, rivers, canals, or pipelines, conditions must be favorable for large-scale interchange of goods between the regions they connect. What are the general underlying reasons for large traffic flows? Probably first in importance is the existence in each of two different regions of large surpluses of certain commodities which are in demand in the other. Examples are the heavy movements of grain, coal, iron ore, and fertilizer raw materials, such as phosphates. Distance is also important. A region will normally secure a needed commodity from the source closest at hand. More-distant sources of supply are sometimes used, however, because of tariffs, quotas, import and export controls, freight-rate manipulations, or lower prices prevailing for the more distant commodity.

All forms of transport, no matter how diverse and no matter how widely spaced over the earth, are basically interrelated in the task of moving surplus products from place to place. Thus the earth is covered by an intricate, interlacing and interlocking mesh of transport routes of various kinds, ranging from the sea lanes to primitive trails suitable only for pack animals. In the journey from area of origin to market, commodities may be forwarded by many different transport media. Primitive forms of transport, based essentially on human and animal muscles and upon the wind, are still an essential part of the total transport fabric. Many products, particularly those originating in the tropics, may be hauled by primitive transport for the first stage of the journey. In the vast area of small, scattered islands lying east of the Philippines, known as Micronesia, the collecting of coconuts from the palm groves on the outlying uninhabited islands of each island group is performed by outrigger canoes. Later, small interisland motor vessels may carry the copra collected on many island groups to Manila, where copra from Philippine plantations and

native farms is also collected. Finally, from Manila large oceangoing freighters may haul thousands of tons of copra either eastward across the Pacific or westward through the Indian Ocean and Suez to the eastern coast of the United States. Conversely, the final segment of the journey of many types of manufactured goods to scattered outlying markets in economically underdeveloped areas may also be effected by forms of primitive transport.

Interrelations between transportation and the earth are of a very fundamental nature. Transportation both affects and is affected by the earth. History is replete with examples of major changes which ensued with the opening up of a new mode of transportation in an area. Construction of numerous separate railroad lines westward into the Great Plains of the United States during the nineteenth century helped transform the Plains from a cattle-raising into a grain-growing area by making it possible for grain to be shipped out cheaply. In the mid-twentieth century the development of iron-ore production in the heretofore remote Knob Lake-Burnt Creek area on the border of Quebec and Labrador in the Canadian north offers a striking example of the effect of transportation on the economic development of the earth's surface. The supplies necessary for initial construction of the iron-mining camp were flown in since no roads reached this area, but the actual working of the ore body and the shipping of ore had to await the completion of a 300-mile railroad built northward from the port of Seven Islands on the St. Lawrence estuary to the mining area. Without the railroad, the cost of shipping the ore to the world's blast furnaces would have been prohibitive.

The earth's surface likewise influences the location and functioning of transport activity. The exact location of ports is often affected by the original existence of protection from storms, such as that afforded at the lower ends or estuaries of rivers or in sheltered bays. The ports of Marseille, Capetown, and New York are examples. The actual orientation of the great sea routes of the world exhibits dependence on the major configurations of continents and the oceans,

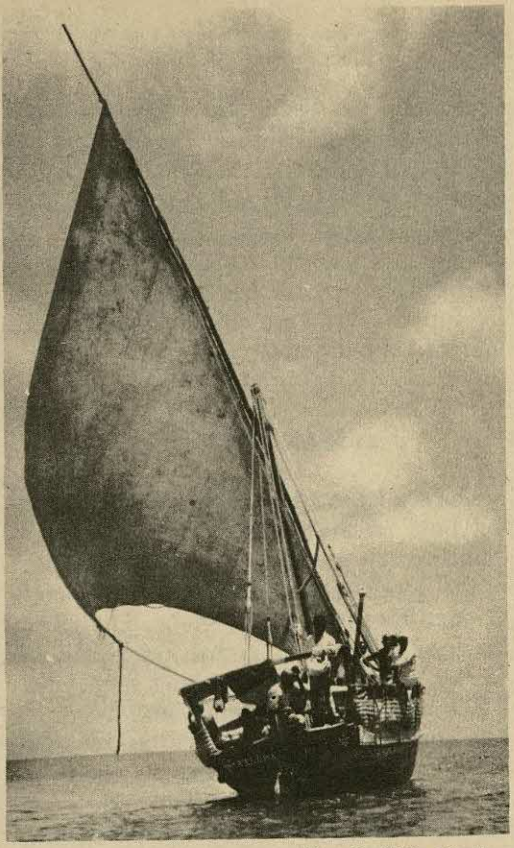


Photo by Walter Deshler

Fig. 368. Arab dhow of 20 tons in the Indian Ocean. Such vessels carry on trade between the lands bordering the northwestern part of the Indian Ocean, from India to Zanzibar. This traffic is an important supplement to long-haul ocean shipping.

since the alignment of the sea lanes is governed not only by the location of the terminal ports but also by the capes, straits, and mid-ocean island groups which influence the alignments of the routes. A similar illustration on land is the main line of the New York Central Railroad, which follows a lowland "water-level" route through the Appalachian highlands by way of the Hudson and Mohawk valleys, even though this routing adds many miles to the rail distance between New York and the Midwest. However, the earth affects transport even more fundamentally than in the alignment of routes and the location of ports. The dense clustering of transport routes corresponds to those parts of the world which have proved favorable for intensive economic development and where a high level of material

civilization has been built up on the basis of the exchange of many commodities. In the United States, for example, the location of vast beds of high-grade, easily accessible bituminous coal, much of it suitable for coking, in the northern and central sections of the Appalachians has had profound effects on the structure of rail-traffic flows in eastern United States.

OCEAN SHIPPING

The sea lanes constitute the longest binding links of the world's economy. Ocean-going vessels assemble and distribute most of the goods that move to and from points situated far apart on the globe. The job of the freighter is truly global; practically all of the world's freight moving more than 3,000 miles does so by ships, and freighters also contribute heavily to the task of moving goods shorter distances, anywhere between 20 and 3,000 miles. The wide range of ocean transport is rendered possible by the fundamental geographic fact that the world's oceans and seas are interconnected, whereas the land areas are disconnected. Unbroken, world-wide ocean voyages can thus be undertaken without the transfer of goods from one carrier to another (Fig. 369).

Ocean shipping makes it possible to assemble diverse goods from far-flung points on the earth without exorbitant costs. The unbroken nature of long ocean voyages is partly responsible for the reasonable level of costs in sea transport. Even more important is the low intrinsic cost of water transportation. It is no more costly to haul freight several *thousand* miles by sea than several *hundred* miles by land. Cheapness of water transport is due to a number of factors. It is not necessary to construct a route, except for the dredging of harbor channels. Transport costs are distributed over large loads, thus lowering the cost per ton, and at comparatively low speeds friction is less than on land. Thus expenditures for power are lower per ton of goods when they are shipped this way, rather than by rail or road.

Transoceanic shipments must of necessity be carried by freighters, except for a small, high-value fraction which may travel by air. Ocean shipping may also compete effectively for traffic bound from one part of a continental area to another if the freight can be moved part or all of the way by *coastwise* ocean transport as an alternative to land transport. In general, the bulkier the goods, the higher the total transport costs, because of the larger amounts of the commodity on which transport charges must be assessed. If the commodity concerned is bulky but of low value per unit, transportation charges, particularly for road or rail, may become quite high in proportion to value. For instance, transport costs for a land haul of several hundred miles may double the costs of bulky items, such as coal and building stone, compared to the cost at point of origin. As a general rule, then, we find that the bulkier the goods, the greater is the tendency to move them over water routes for as much of the total journey as feasible, in order to take advantage of lower ton-mile costs of water carriers. Shipping thus plays a vital role in providing comparatively low-cost transportation for goods moving in both intercontinental and intracontinental trade.

Convergence of shipping on Western Europe. World shipping focuses on Western Europe. The greatest concentration of shipping is found in the waters off the coast of Europe between the southern tip of Norway and the northwestern corner of Spain. Almost 40 per cent of all ocean voyages originate or terminate in this part of the world, so restricted in area yet so attractive to world shipping. In the English Channel, the Strait of Dover, and the North Sea and in the waterway approaches to the great ports of London, Liverpool, Rotterdam, Antwerp, Hamburg, and others, the circulation of traffic is particularly intense. Frequency of ship movements in European waters contrasts strongly with the emptiness of vast oceanic areas; one could sail or fly across the Pacific Ocean without encountering a single ship.

Along the sea lanes leading to Western Europe, cargo liners, tramps, tankers, and refrigerated vessels move in large numbers, carrying foodstuffs and raw materials to-

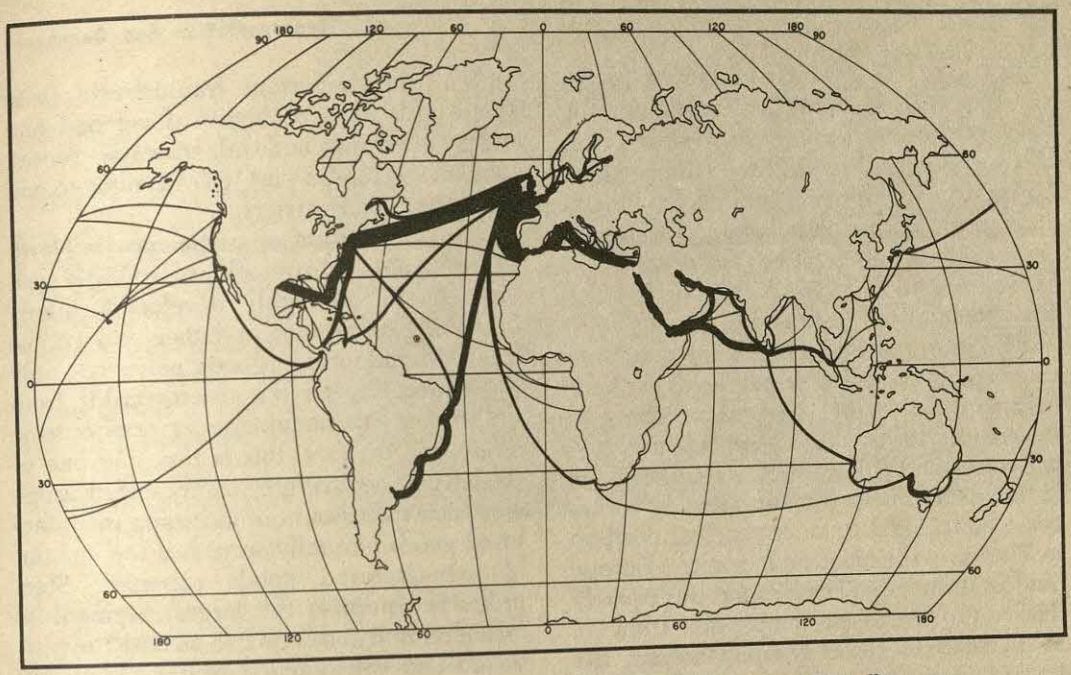


Fig. 369. Principal sea lanes of the world. Thicknesses of lines indicate the volume of traffic. Relative importance of the various routes is only approximate. Minor routes are not shown.

ward Europe and manufactured goods on the outbound voyages. The inflow of foodstuffs and raw materials is directed toward the densely populated, highly developed industrial area which extends from Great Britain eastward to Germany and southeastward to Austria and northern Italy. This is one of the two great manufacturing areas of the world. Combined with the fact that European factories need many raw materials which must be brought from overseas is the inability of industrial Europe to feed itself completely because of its dense, primarily urban population. Consequently, raw materials for factories and foodstuffs for factory workers make up the largest part of incoming cargoes unloaded at European ports. Thus the factors that gave rise to a major manufacturing area in Europe, discussed in Chapter 29, have, in turn, a profound effect on the world transportation pattern.

The sea-borne raw materials destined for European ports are frequently bulky items which either cannot be produced in Europe at all or can be produced there only in sufficient quantity. Examples are phosphates, wool, petroleum, and crude rubber. Chief among the foodstuffs are wheat, corn, meats from middle latitudes, and a host of tropical products, coming either from plantations or from native commercial producers. Some of these tropical products are coffee, bananas, raw sugar, cacao, copra, and vegetable oils. Since the greatest concentration of heavy manufacturing, the greatest population densities, and the greatest proportion of urban dwellers all occur in an axial area extending from England through the Low Countries and northern France into Germany, we find that the greatest amount of traffic is handled by the major ports serving this area. Outward from this zone of maximum manufacturing and maximum population density the requirements for raw materials and foodstuffs drop off considerably, but they remain high enough throughout most of the continent to support considerable traffic to other ports on the coast of Europe.

The outflow of traffic tonnage from Europe was formerly more nearly equal to the inbound tonnage, because Europe exported large amounts of coal to far-flung points ranging from the Pampa of Argentina to Capetown and India. The principal areas of origin of this coal export trade were the two

British coal fields which lie closest to the coast, namely the South Wales field and the field on the northeast coast of England in the vicinity of Newcastle. Tramps which brought bulk cargoes of grain or raw materials to European ports would customarily proceed to a port such as Cardiff in South Wales to load a cargo of coal for haulage back to faraway destinations. These large-scale coal shipments from Europe permitted more freighters to carry pay loads on both outbound and return voyages, resulting in lower rates for the haulage of inbound raw materials, and this in turn was one of the factors which helped manufacturing to become established in an entrenched position in Europe in the nineteenth century. Europe has lost its long-haul coal export trade partly due to the increased competition from oil fields, such as those grouped around the Persian Gulf and in Venezuela, the development of overseas coal fields, such as those in India, and the increased efficiency in the use of coal. Indeed, in recent years Europe has even been a net importer of coal, since its own mine production has had difficulty keeping pace with its mounting coal requirements. As a result, tonnage moving to and from Europe has become more unbalanced, since many types of manufactured goods are not so bulky as the raw materials from which they are manufactured. The relatively small volume of the manufactured goods outbound from Europe is no longer supplemented by bulky exports of coal, which now makes it necessary for some outbound shipping to carry nonremunerative ballast.

The North Atlantic route. From the ocean fringe of Western Europe major sea lanes radiate out in several directions (Fig. 369), including the one leading to the section of North America between Hampton Roads, Va., and Montreal. This North Atlantic route has the heaviest shipping density of all ocean routes, and the total ton-mileage of its freight traffic surpasses that of any other route in the world. It connects the world's two major manufacturing regions, the two areas of the globe having the highest level of industrial and commercial development and the highest standard of living. Behind the ports located at either end of this important transatlantic route there is a mesh of highly developed and integrated land and inland-water routes, which functions in part to feed traffic to and from the ocean carriers.

The composition of traffic on the North Atlantic route is extremely varied. This variety reflects the highly developed, highly organized economies at either end of the route. Manufactured goods move not only away from Europe, but also toward it, from the only great manufacturing area outside of Europe. In fact, this is the only one of the sea lanes converging on Western Europe on which the amount of incoming manufactured goods normally surpasses the amount of manufactured goods exported. Steel products comprise the largest segment of manufactured goods carried on both the eastbound and westbound voyages, an indication that the types of steel manufacture are not identical on both sides of the North Atlantic Ocean. Prominent among eastbound foodstuffs are wheat and corn. Shipments of raw cotton from the ports on the Gulf of Mexico also move eastward over the North Atlantic route, since the short great-circle route from the Gulf to Europe actually extends across the North Atlantic. Westbound traffic across the North Atlantic includes a few bulky raw materials, such as iron ore from northern Sweden destined for that segment of the American iron and steel industry situated on the Atlantic coast. Agricultural products moving westward across the North Atlantic are likely to be very specialized commodities, such as French wines, Mediterranean olives, and special types of cheese, moving in far smaller lots than the bulk shipments of grain from North America. The large fleet of passenger liners, including the famous luxury liners which race between New York and European ports, comprise a colorful segment of this North Atlantic shipping, but the contribution of these liners to the humdrum business of moving cargoes back and forth across the ocean is negligible in contrast to that of the freighters in operation on the route.

The Mediterranean-Red Sea route. Western Europe is likewise the terminus of the world's second most important sea route,

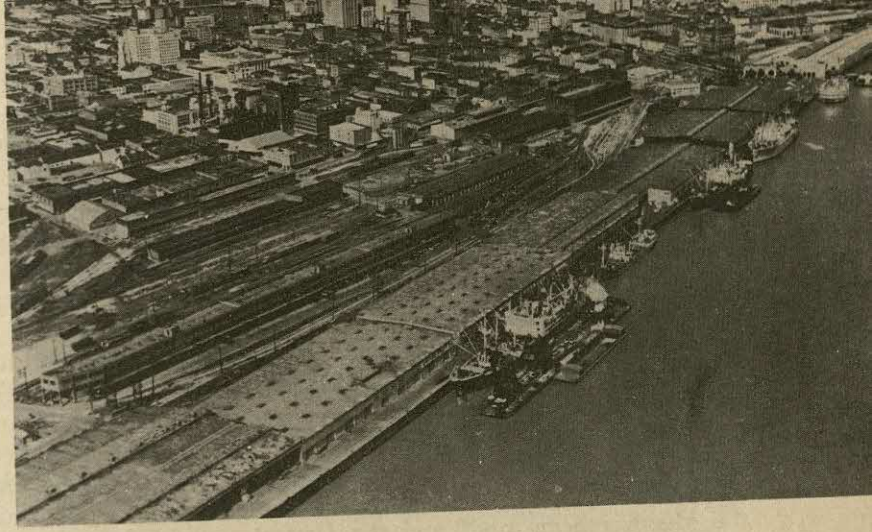


Fig. 370. Part of New Orleans, loading and unloading of vessels can be from and to wharf, and from and to lighters equipped with heavy-lift cranes. Note the extensive rail facilities and those for trucks. Central business districts of New Orleans in the background.

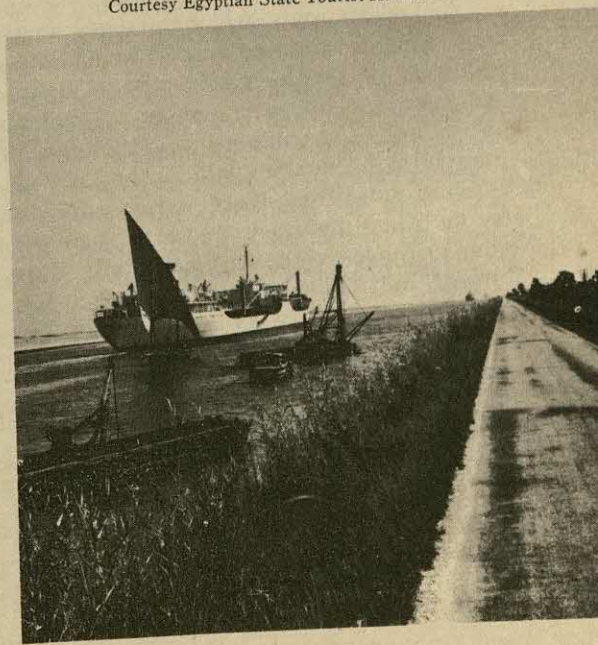
Courtesy Bureau of New Orleans News and Chamber of Commerce of the New Orleans Area

which leads through the Strait of Gibraltar, the Mediterranean Sea, the Suez Canal, and the Red Sea into the Indian Ocean. Once in the Indian Ocean the route splits: one important lane curves northeast toward the oil-shipping ports of the Persian Gulf, a minor one diverges down the east coast of Africa, while the principal lane continues eastward toward India and Ceylon. At Ceylon the main route splits again into three major components, leading, respectively, northeastward into the Bay of Bengal, southeastward to Australia, and eastward toward Malaya, Indonesia, and the Far East. The Far Eastern lane extends northeastward to Hong Kong and Japan, where the easternmost extremity of this route converges with the North Pacific route coming from the United States.

Since all ships on this route must go by way of the Suez, the canal provides a good check on the nature of the traffic between Europe and the United States on the one hand, and Asia and Australia on the other. Tanker-borne oil cargoes from the Persian Gulf have come in recent years to dominate tonnagewise the northbound traffic through the Suez Canal, surpassing the total of all westbound cargoes from all other origins. The opening up of oil pipelines between the producing fields and the terminals at the eastern end of the Mediterranean Sea has, however, somewhat limited further increases in such oil traffic. The steady succession of freighters which head northward through the Red Sea toward Europe carry some sharply contrasting types of cargo, reflecting the diverse physical and human environmental conditions of the major source areas. The Australian segment of the traffic is almost completely middle-latitude agricultural in character; refrigerated beef and mutton, together with wheat and wool, are preponderant. From the India-Pakistan and Southeast Asia lanes come an array of tropical products from one of the world's two most highly developed tropical plantation areas, supplemented by contributions of

Fig. 371. The Suez Canal. Note that several ships are visible. The Suez Canal, unlike the Panama Canal, is a sea-level canal and contains no locks.

Courtesy Egyptian State Tourist Administration



native farmers who have added items of commercial production to their subsistence agriculture. Ferroalloys, bulk tea, some raw silk, and Japanese manufactured goods are some of the items included in the traffic originating in the Far East.

Some of the traffic from western Europe is purely Mediterranean in destination and does not enter the Suez Canal. The lands of the Mediterranean basin send iron ore and other metallic minerals, phosphates, fruits, and raw cotton to western Europe, whereas coal, timber, and a host of manufactured goods go from northwestern Europe to the Mediterranean ports. Interchange between the Mediterranean lands and the United States shows similar patterns, including the export of American coal to the fuel-deficient lands east of Gibraltar.

Not all the shipping which sails north and south off the west coast of Europe between Spain and the British Isles follows the Mediterranean route or its extension through the Red Sea into the Indian Ocean. A large volume which clears the northwest coast of Spain is committed to one or the other of two great routes, both of which lead south below the equator, one along the east coast of South America and the other along the west coast of Africa to Capetown (see Fig. 369), indicates that ships proceeding from western European ports to either Capetown or the east coast of South America follow essentially the same route until approximately latitude 20° N. is reached, the latitude of the Cape Verde Islands.

The ocean route which diverges south and west, toward the east coast of South America, passes along 2,000 miles of Brazilian coast, touching at a number of Brazilian ports, and then continues to the Pampa of Argentina, where the ports of the La Plata estuary form the major terminus of the route. Along this route moves a major portion of Europe's external food supply. Corn, wheat, and chilled and canned meat originate principally in the agriculturally productive areas inland from Buenos Aires and Montevideo. From tropical ports farther north come products such as coffee and cacao. Formerly coal exports from Europe provided a backhaul from Europe to South American ports, but now southbound shipping frequently must sail in ballast.

Africa-Indian Ocean routes. The Capetown route from Europe is mainly used as a through route by shipping bound not only to and from Capetown but also to ports on the Indian Ocean side of Africa and in Australia. The Capetown route is almost completely separate from the local shipping lines which run from Europe to a series of ports along the West African coast. In spite of the importance of a few tropical exports from Africa, such as cacao shipped through the port of Takoradi in Ghana and of Katanga copper through the ports of Matadi and Lobito, the tropical parts of the African continent are not outstanding in the production of commercial products, particularly when compared to the Caribbean area or Southeast Asia. The through Capetown route consequently carries a far larger volume of shipping than the local lines putting in at the scattered ports along the west coast of Africa.

Beyond Capetown the route forks, and one branch leads north toward ports on the southern part of the African east coast, including the port of Beira, through which most of the copper of Northern Rhodesia is exported. The other branch leads east across the Indian Ocean to Australia, where it is met by the Ceylon-Australia fork of the Mediterranean-Red Sea route. Although South Africa imports considerable quantities of European manufactured goods, both the mineral and the agricultural exports of the republic taken together are not sufficient to provide full cargoes for much of the shipping arriving at Capetown from Europe. Consequently freighters steam eastward to Australia, a far more important source of full cargoes due to the large volumes of grains, meat, wool, and dairy products. Australia, with its extensive grain farms and cattle and sheep stations, combined with its low population density and its small internal market, is one of the world's larger source regions for the export of agricultural products.

Ships returning to Europe from Australia have a choice of routes. The faster cargo liners return mainly via Suez, allowing them

to pick up tropical products from Ceylon or India enroute. The slower grain-carrying tramps normally return via the Capetown route, a thousand miles longer than the Suez route but toll-free. A few ships even sail eastward from Australia and return to Europe via New Zealand and the Panama Canal. Thus several of the ocean routes terminate in Australian water, routes which, 12,000 miles away on the other side of the earth, come together again in European ports.

The eastern coast of North America. The array of ports along the Atlantic coast of the United States from Hampton Roads, Virginia, to Montreal, Canada, constitutes the second largest focus of shipping in the world and includes the world's largest single port, New York City. Although New York City surpasses any single European port in the volume of its activity, the total activity of the North Atlantic ports of North America is below that of the northwest European ports. As is the case in northwest Europe, the American Atlantic ports are backed by an area of high population density, high development of land transportation, and outstanding industrial productivity. In addition, the North American interior is enormously productive agriculturally, with an output so far in excess of internal consumption that the world's largest exportable surpluses originate on this continent. Through New York and its flanking ports passes the bulk of American imports and about half the total exports (Fig. 369).

From these ports the North Atlantic sea lane discussed previously leads off to the east, while a whole host of routes fan out to the south. Aside from the main route to Europe, the north-south orientation of routes focusing at New York is striking. Four routes in particular stand out: (1) the one toward the eastern bulge of Brazil, where it joins the route from Europe to the east coast of South America; (2) the route toward the petroleum fields of Lake Maracaibo, Venezuela; (3) the sea lane to Panama, for Pacific Ocean destinations; and (4) the coastwise route around Florida to Gulf ports. Many of the vessels on the Lake Maracaibo and the Gulf ports routes haul crude and refined petroleum to the largest American refinery and consumer market, the New York-Philadelphia area. American shipping on the sea lane to the east coast of South America is destined primarily to Brazilian ports, particularly to Rio de Janeiro and to Santos, the port for the São Paulo coffee lands. This is in contrast to European shipping, the most active trading business of which centers in the ports of the La Plata region farther south. This difference results from the fact that, whereas Brazil and the United States trade tropical agricultural products and minerals for manufactures and middle-latitude agricultural products, the European countries require further food imports from the middle-latitude La Plata region, but tend to favor their former colonial areas rather than Brazil for tropical foodstuffs and raw materials.

The Panama route leads to the Panama Canal, the gateway to the Pacific. Once clear of the canal, the route splits, one branch reaching down the western coast of South America, another heading toward the West coast of the United States, and several minor routes leading out to Pacific island destinations.

The opening of the Panama Canal in 1914 effected a major relocation of ocean steamship routes, just as the opening of the Suez Canal almost half a century earlier, in 1869, revived the Mediterranean route to India and the Far East, thereby restricting the Capetown route to shipping destined primarily to and from South African and Australian ports. Although European trade with the west coasts of both North and South America, the Pacific islands, and New Zealand now makes use of the Panama Canal, the greatest relative gain in distance saved with the opening of the new waterway was on the sea route connecting the East and West coasts of the United States, which formerly went around Cape Horn. Sailing distances were cut by more than two thirds, and intercoastal water-borne traffic between the Atlantic and Pacific coasts, distinct from coastwise traffic which does not move through the canal, greatly improved its position, which had suffered since the completion of the first transcontinental railroad in

1869. Comparatively heavy intercoastal traffic developed in both directions, and such traffic accounts for the largest part of the bulk shipments between the East and West coasts of the United States.

The strengthening of the intercoastal route via Panama had important geographical repercussions. The increasing quantities of lumber from the softwood forests of the Pacific Northwest destined for the northeastern United States were diverted almost entirely from the railroads to intercoastal shipping. The westernmost grain lands of the Canadian Prairie Provinces turned about-face and began exporting wheat through Vancouver, thus eliminating the long overland and Great Lakes haul to Atlantic ports. Conversely, manufacturers in the northeastern states, adjacent to Atlantic ports, were able to deliver finished goods to West coast markets since they now had the advantage over their competitors in the Midwest, who were located too far from the Atlantic coast to enjoy cheap ocean-shipping rates and were confronted by land-transport rates to the West coast higher than the water rates from the more distant Atlantic coast. Intercoastal traffic between the two sides of the North American continent affords interesting comparisons between land and water transport and is discussed again later.

Trade between American Atlantic ports and the west coast of South America has been important for almost 150 years, long antedating the Panama Canal. The rise of the port of Baltimore, for example, was accelerated by the brisk trade in guano and copper, coming respectively from small islands off the coast of Peru and from Peru and Chile. Minerals continue to be the principal cargo from this part of the world—nitrates, copper, ferroalloys, tin, and petroleum—contrasting with the predominance of agricultural products in the cargoes originating along the east coast of South America. Since the opening of the canal there has been little incentive for shipping to move beyond central Chile, and many freighters go no farther south than the ports of Peru or the nitrate ports of northern Chile.

The Pacific. The vast Pacific Ocean covers one third of the surface of the entire earth, yet at any given time there are far fewer ships making their way across the Pacific than across the Atlantic, including its connecting seas. Furthermore, during the twentieth century the share of the Pacific Ocean in world shipping has declined. Why does the world's greatest ocean have such a low density of shipping? In the first place, the very size of the Pacific induces ships traveling between Europe and either the western coast of North America or the Far East to turn their backs on the Pacific and proceed homeward via shorter routes. The Pacific covers a vast area and has no large islands where important shipments can originate or terminate, and it lies on the opposite side of the earth from the focus of maritime activity in Western Europe. Secondly, around most parts of this great ocean basin, high mountain ranges rise close to the coast, leaving little room for productive agricultural lands. With the exception of the Far East, the great areas of human economic activity face in directions other than the Pacific, the clusters of population in California and the Pacific Northwest being of only a secondary order of magnitude. Thirdly, neither of the two great manufacturing regions of the earth front directly on the Pacific. Finally, as we shall see, there are still more immediate reasons for the relative decline of Pacific trade routes.

The one important trade route extending across the Pacific has its western terminus in Yokohama, Kobe, and Osaka, ports located along the southern coast of the main island of Japan. Towards North America it splits into a lane leading to the Puget Sound group of ports, while another leads nonstop across the Pacific to San Francisco, with an extension to Los Angeles. The Hawaiian Islands, the "crossroads of the Pacific," are by-passed far to the north by this one important arterial route of the Pacific area, since the much shorter great-circle route is preferred to a detour via the Hawaiian Islands, which adds almost 2,000 miles to the trip from California to Japan.

Flow of cargo along this route to and from eastern Asia and North America is badly unbalanced, the westbound tonnage being much greater than the eastbound.



Fig. 372. Coastwise shipping. Small motor vessels of less than 1,000 tons cargo capacity operate along coastlines in many parts of the world. This small coasting vessel is unloading kerosene and loading wool at a small, isolated New Zealand port beyond the reach of rail transportation.

Photo by Donald Patton

This disparity is due to the demand in the Orient for North American bulk products, such as lumber, grain, raw cotton, and petroleum, together with some American manufactures and semimanufactures, while the Orient is unable to make up return cargoes of comparable volume. East Asia is in no position to export foodstuffs (except specialties such as tea) or raw materials, as it needs the latter for its own manufactures, while its shipments of manufactures are inadequate to fill the holds of vessels for a return journey across the Pacific. The low volume of eastbound trade has further declined due to: (1) the shrinkage of Japanese exports of raw silk to the United States, as a result of the competition of synthetic fibers; and (2) the virtual suspension of trade between the United States and the ports of the Chinese mainland since the advent of Communist control of China in 1949.

A complementary trade relationship has consequently developed in the western Pacific area between the Japan-China region and Southeast Asia, including the Philippines, Indonesia, Malaya, and Thailand. It has become a common practice for freighters to discharge American cargo in Far East waters, then proceed southward for loadings in the Southeast Asian realm of surplus tropical agricultural products and minerals. The critical importance of Southeast Asia to the United States, as well as to Europe, is exemplified by Malaya, which through its sales of crude rubber and tin has been the largest dollar earner in the entire British Commonwealth in a number of recent years. Once ships have loaded cargo in Southeast Asian ports, it is shorter to return to American eastern coast ports via the Red Sea, Suez, and the Mediterranean. This tonnage helps to swell the European traffic on the same route, but leaves the North Pacific route with a predominance of westbound over eastbound shipping.

This brief survey of the world's leading shipping routes has only touched upon the more important sea lanes. The patterns of world shipping are very complex and change constantly, encompassing a multitude of minor trade links forged by isolated voyages of tramps, which may be broken as often as economic conditions change. Multitudinous sailings of shallow-draft vessels are also important to the total movement of goods, particularly of those engaged in the "short-sea" coasting and coastwise traffic in European waters and of the small craft used on the inshore routes that flank the coasts of southern and eastern Asia.

LAND TRANSPORTATION

Not until the second quarter of the nineteenth century did land transportation begin to undergo a profound transformation. For at least several thousands of years prior to the nineteenth century, the movement of goods over land routes was slow, arduous, and costly. Land transport of freight was usually avoided if there was any possibility of using water transport. The relative ease with which the small, shallow-draft ships of former centuries could ascend even minor streams increased the range and efficiency of water transport throughout most of the era of recorded history. The sudden emergence of relatively efficient land transport, spearheaded by the development of the railroad and rendered possible by the Industrial Revolution, created a veritable transport revolution. For the first time the large disparity in the costs per ton-mile of moving freight over a land surface compared to a water surface was sharply reduced. Competition of land transport with water transport became more effective after the beginning of the railroad era.

During the past century increasingly efficient land carriers have been successful in diverting some coastwise traffic which otherwise would move by water routes, although short-haul water transportation remains very important along the coasts of Europe and southern and eastern Asia.

But the revolution in land transport had even more profound consequences. The economic resources of continental interiors became more accessible, and the development of such areas as the Great Plains of the United States and Canada, the Pampa of Argentina, and the interior plains of Australia was speeded by the advent of rail transport which could haul out agricultural products at rates low enough to enable the output of the new agricultural areas to be competitive on the world market. This advantage of low production costs per acre on cheap new lands was implemented by relatively low land-transport costs. The English landlord of the mid-nineteenth century was experiencing one aspect of the new transportation when he found overseas wheat coming into England at prices below his own cost of production. The modernization of land transport, which has further gained in efficiency as rail travel has been supplemented, and in some cases replaced, by motor transport on modern hard-surfaced highways, has permitted intracontinental traffic and passenger circulation to develop on an enormous scale. A high volume of interchange of raw materials, foodstuffs, and manufactures, largely dependent on rail and road transport, has developed within parts of North America and Europe and, to a lesser extent, in Asia. With each technological advance in land transport, the interchange of goods between two points on the same land mass via an all-land route has been encouraged, and, in a sense, those continental areas which have undergone the greatest material development have ceased to face oceanward to the extent formerly characteristic of their transport relationships.

Railroad transport. Railroads are the mass movers of freight on land. Inherent characteristics of railroads make them so. The tractive power of a train moving over smooth steel rails is distributed over a large load in many cars totaling up to 10,000 tons. The movement of a train over a special type of route uncluttered with public vehicles allows an elaborate control of speed, length of carrier, and timing of movement, thus making possible a combination of heavy pay loads and flexible operations. However, heavy freight trains are highly sensitive to even low slopes, and almost all of the world's heavily traveled lines have a maximum gradient under 2.5 per cent. Railroads do not avoid hills and mountains, but in detail the location of a rail route poses many problems of a geographical and engineering nature in areas where up and down grades are unavoidable. As traffic increases or shows promise of increasing, the rail right-of-way is systematically improved in order to permit it to handle more trains per day. Enormous differences exist in the capacity of railroads to carry traffic. Evidences of high traffic density are multiple tracking (either two, three, or four tracks), heavy rails, thick

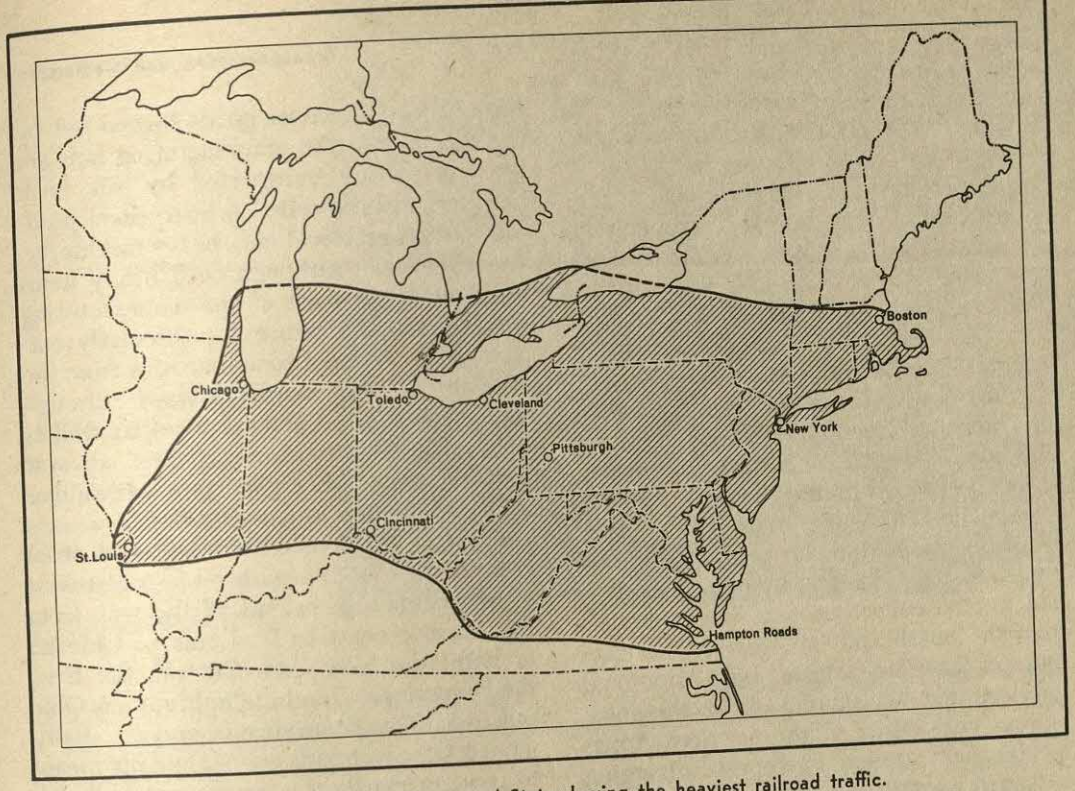


Fig. 373. Map showing the section of the United States having the heaviest railroad traffic. Railroad facilities for handling heavy traffic reach their peak in this area. Note that the shaded area corresponds closely with the major manufacturing area of the United States, and includes the principal coal-mining regions.

stabilizing ballast, low grades and gentle curves in hilly and mountainous country, and advanced, complicated electronic signaling systems installed along the railroad to permit closer spacing of trains. In parts of the world where few locomotives are of the diesel type, further advances in traffic-carrying capacity, as well as savings in operating cost, have been effected by electrifying the lines where density of traffic and cost of electricity warrant it. For example, average running time of trains over difficult mountain country between Bergen and Oslo, Norway, was reduced about 40 per cent after electrification of the line. Finally the gauge of the track is important. Narrow-gauge lines normally carry less traffic than standard-gauge or broad-gauge lines.

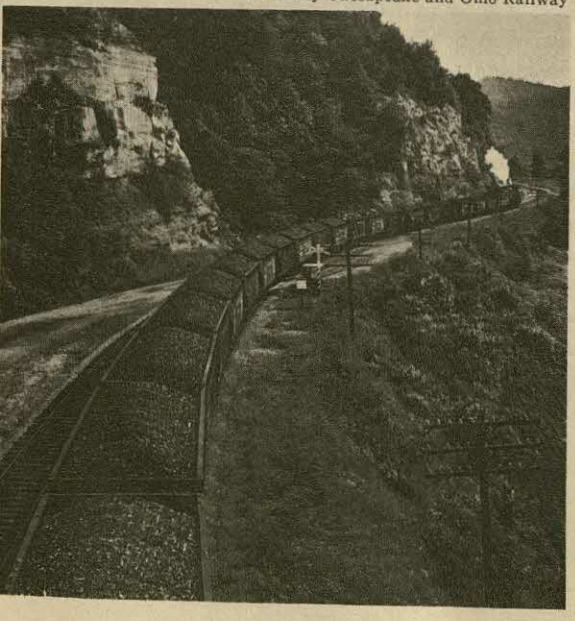
NORTH AMERICA. The United States and southern Canada have the world's most extensive rail network and the world's most technically advanced methods of railroad operation. In their ability to move heavy tonnages of freight long distances at comparatively high speeds and at low costs per ton-mile, American railroads are in a class by themselves. Operational features of railroads on the North American continent are symptomatic of unique features of North American geography, including the existence of some superlative natural resources, outstanding in both quality and quantity, and their exploitation and transportation, often over long distances, as part of a production process geared for large-scale production for a mass market. The special qualities of North American rail transport are enhanced even further in the northeastern part of the United States (Fig. 373), which contains the main manufacturing belt of the continent and the most intensively developed coal fields. Here occur the heaviest rail traffic flows of the world. This unique railroad region fronts on the North Atlantic coast from Hampton Roads, Virginia, to Boston, Massachusetts, where the

ports comprising the western terminus of the great North Atlantic sea lane are also located.

The main railroad systems in the northeastern United States extend predominantly in an east-west direction. The longest of these trunk lines reach their western termini in Chicago, and St. Louis. Washington, D.C., Cincinnati, St. Louis, and Chicago are gateway cities into this trunk-line territory from the South and the West. The main east-west stems are mostly double- or multiple-tracked and have the world's heaviest rails. Traffic is speeded by the widespread use of the most advanced signaling systems. Heavy traffic is generated in part by the eastbound movement of foodstuffs from the Midwest and by the convergence of raw materials from the South and the West on the factories of the manufacturing belt. Additional heavy traffic flows originate at the bituminous coal mines of the northern Appalachian field around Pittsburgh, diverging eastward toward the Middle Atlantic coast and New England and westward toward the Midwest. Heavier goods turned out by the factories of the manufacturing belt are likewise mainly transported by rail. Such products include rolled primary-steel products, structural steel items, heavy machinery, and chemicals. Although such heavy items originate in all parts of the manufacturing belt, their manufacture is particularly outstanding in an axial zone that runs from the Pittsburgh area northwestward through Youngstown, Ohio, to Cleveland, as well as in a strip that extends along the southwest shore of Lake Michigan from Milwaukee through Chicago to Gary, Indiana.

Fig. 374. Chesapeake and Ohio Railway coal train northbound from the eastern Kentucky section of the southern Appalachian coal field. Solid coal trains of 150 or more cars originate in this area.

Courtesy Chesapeake and Ohio Railway



Railroad transportation in the industrial Northeast depends heavily on four east-west trunk lines which extend all the way from the Atlantic coast to St. Louis or Chicago or both: the New York Central, the Erie, the Pennsylvania, and the Baltimore & Ohio railroads. The Pennsylvania and the Baltimore & Ohio railroads were originally meant to serve primarily the interests of Philadelphia and Baltimore respectively, and to carry western trade to and from these ports. With the outstanding development of New York both as a port and a metropolitan center, however, both the Pennsylvania and the Baltimore & Ohio railroads were forced to acquire access to New York. Today a good deal of freight rolls right through Baltimore and Philadelphia bound to or from New York, further enhancing the pre-eminent position of that city and port. All four main east-west trunk lines, together with other important but shorter lines, make use of a series of twisting valleys to worm their way through the Appalachians with the minimum amount of mountain climbing. All traffic moving by rail between the Atlantic seaboard and the trans-Appalachian interior converges on the main-line "bridge routes" which funnel it through the Appalachians. The channeling of traffic to these bridge routes cutting through the mountains results in extremely heavy flows of traffic along these routes. The main line of the Pennsylvania railroad, for example, divides at Pittsburgh and Harrisburg, the western and eastern exits of the trans-Appalachian route of this carrier, but the three-track main line through the mountains between these two

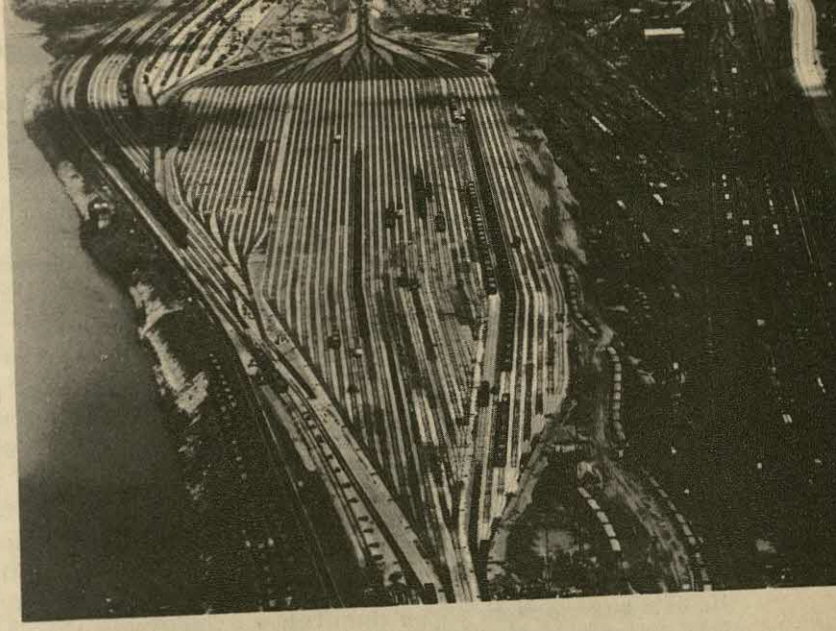


Fig. 375. Large railroad classification yard of the Pennsylvania Railroad at Conway, Pennsylvania, near Pittsburgh. The 54 tracks shown are for classifying eastbound trains.

Courtesy Pennsylvania Railroad

points carries the heaviest flow of land traffic in the world. In a larger sense, however, the Pennsylvania Railroad owes its heavy traffic density east of Pittsburgh and along many other sections of its system to its central location in the American manufacturing belt (Fig. 375).

South of a line from Washington, D.C., through Cincinnati, Ohio, to St. Louis, Missouri, the meshes of the railroad network become larger, and the average density of traffic lightens, except for the areas tributary to the main lines of two railroads: the Chesapeake & Ohio and the Norfolk & Western. These railroads, sometimes given the collective name of the "Pocahontas roads," are the most specialized coal-hauling lines in the United States. Their coal originates in the central part of the Appalachian coal field, the mining districts of southern West Virginia, and contiguous parts of western Virginia and eastern Kentucky. About one third of the coal output rolls eastward downgrade to Hampton Roads in solid 150-car coal trains for ultimate export or coastwise shipment to New England. The remaining two thirds of the mine output move northwestward to the Midwest. Some of this interior-bound coal moves to its destination entirely by rail, while some of it is transshipped to lake carriers at Toledo, Ohio, which in recent years has developed into one of the world's leading coal ports. The tonnage of traffic originating within the Appalachians and using these two railroads rivals that moving on the main line of the Pennsylvania Railroad, but the composition of the freight is far less diversified than it is on the main trunk lines farther north. Because of the solid trainloads of coal which can be routed for hundreds of miles without reclassification, there are probably no other railroads in the world where operating costs are lower per ton-mile (Fig. 374).

South of these two systems typically southern railroad conditions prevail. Traffic densities are much lighter than in the Northeast; even main lines are single or at most double tracked, and there are proportionally more lightweight, single-track lines not provided with advanced signaling equipment. Agricultural products and forest products, such as lumber, pulpwood, and naval stores, are relatively more important, while manufactured goods are less important. Mineral traffic is spotty, being very important on lines which serve major mining or quarrying areas, such as those connecting the Florida phosphate beds with Tampa. Seasonal northbound traffic of fresh fruits and vegetables is important on the lines running northward from Florida, particularly on the main lines parallel to the Atlantic coast.

West of a line from Chicago and the Mississippi river cities of St. Louis and Memphis to New Orleans, railroads and their

traffic begin to assume still other characteristics. This large area can be designated as the western railroad region, although it overlaps into the South and the Midwest. Here the so-called transcontinental lines again give a pronounced east-west pattern to the rail network as a whole. These transcontinentals, such as the Union Pacific, the Milwaukee Road, and the Santa Fe, connect the populous eastern half of the United States with the belt of population along the Pacific coast. So pronounced does the east-west rail pattern become in the area between the 100th meridian and the Pacific coast that the traveler finds it virtually impossible to travel any considerable distance by rail in a north-south direction!

In this large western region the density of the railroad network is much below what it is in the South, especially west of the eastern border of the middle-latitude steppe climate, where most of the light interstitial lines between the main through lines die away for lack of traffic to feed on. The economy of much of the West is evidenced by the importance of minerals and agricultural products, including livestock, hauled on the rails, although truck transport is rapidly cutting into the latter. Forest products are important along the Pacific coast; elsewhere they comprise only a small percentage of the total traffic. In this region manufactured goods are predominantly westbound from the manufacturing belt, but they are greatly outweighed by foodstuffs and raw materials. Average length of haul surpasses not only that in the rest of the United States but practically in the entire world.

Canadian railroads are similar to those in the United States, and functionally they are closely related. They are organized into transcontinental systems that connect the discontinuous areas of settlement of the Maritime Provinces, the St. Lawrence Valley, southern Ontario, the Prairie Provinces, and the western coast. Lightest traffic occurs in the region north of Lake Superior and Lake Huron, where virtually all bulk freight is diverted to lake carriers for greater economy of transport.

EUROPEAN RAILROAD NETWORKS. The second great railroad network of the world is in Europe. The Western European ports on which world shipping converges are served by a rail network that is more closely meshed than its American counterpart, and which is characterized by many other features of superior railroad engineering. However, European and American railroads contrast with each other in many aspects of construction and operation reflecting differences in transportation problems on the two continents. These contrasts are rooted in basic geographic differences between the two areas.

European railroads have the same gauge as North American railroads, 4 feet, 8½ inches. The contrast in carrying capacity between main lines and secondary lines is much less than in the United States, but average carrying capacity is lower. Such technical features as weight of rails, thickness of ballast, maximum axle loads on bridges, and signaling facilities on the European lines are all geared to lighter freight-loads. Lines are frequently double tracked, but the three- and four-track lines which exist in the industrial Northeast of the United States are extremely rare in Europe. European lines operate efficiently under conditions prevailing in the area. Population density is extremely high; cities, factories, mines, quarries, and ports are close together; rail junctions are numerous, and flexibility of rail transport is needed. European freight cars are small, and freight trains are much shorter than those in North America. Freight trains halt frequently to load and unload, and freight cars are reshuffled at close intervals. In summary, railroad freight originates and terminates in smaller lots but at more places than in the United States.

The close mesh of the railroad network and the rail facilities for carrying traffic are most pronounced in northwestern Europe, where they coincide with the European manufacturing belt, just as a similar relationship exists in North America. Railroad facilities are excellent in all the countries bordering the North Sea as well as in Switzerland and Austria. Technical facilities for supporting heavy freight traffic, such as weight of rail and maximum axle loads on bridges, are most advanced in Belgium,

whose lines carry a large amount of through international traffic as well as local traffic, but the coal mining and industrial area of the Ruhr is served by the closest network of lines on the continent. Rail facilities remain good as far south as central Italy and northwestern Yugoslavia and eastward as far as western Czechoslovakia, but farther to the east, southeast, and south the rail network becomes thinner, traffic densities decline, and railroad technology is less advanced. In the Balkan Peninsula, for example, narrow-gauge lines become conspicuous, and many parts of the peninsula are inaccessible to standard-gauge trains.

RAILROADS IN OTHER PARTS OF THE WORLD. Rail networks have been constructed in a few areas of the world outside Europe and North America. Most of these networks are completely isolated from each other.

In India and Pakistan the railroads are a British legacy. In the Indian subcontinent the construction of an adequate railway network increased the cohesiveness of this large area; this in turn contributed to the rise of national consciousness and the eventual demand for independence. The network is particularly dense in the Gangetic Plain between Delhi and Calcutta, the zone of greatest population concentration. The broad-gauge (five feet, six inches) Indian and Pakistan *national* networks interconnect at numerous points with narrow-gauge (three feet, six inches) *regional* lines; these in turn may interconnect with still narrower-gauge (two feet and two feet, six inches) *local* lines. The tea gardens of Assam and Darjeeling, for example, are served by some of these local, narrow-gauge lines.

In Japan the construction of a comparatively dense railroad system followed rapidly upon Japan's decision in the mid-nineteenth century to westernize itself, and this abruptly ended its medieval isolation. The rugged, mountainous nature of Japan encouraged the construction of narrow-gauge lines which could be built through difficult country with fewer engineering obstacles and consequent lower cost. Railroad transportation, however, is subject to intense competition from coastwise shipping, since much of Japan is not far from the sea, and most important cities are located on the coast.

The railroads of the Soviet Union represent an eastward thinning out of the European rail net. At the western border of the Soviet Union the gauge jumps from standard to broad, in this case five feet. The area of main development of the Russian rail net is triangular in shape, the base of the triangle being represented by a line from Leningrad to Odessa on the Black Sea, the tapering apex of the triangle extending far eastward, across the Urals into western Siberia. To the northeast lies the sparsely populated coniferous forest, while to the southeast extend the middle-latitude steppes and deserts of southeastern European Russia and central Asia. From the apex of the triangle in western Siberia, the double-tracked trans-Siberian line continues on to Vladivostok on the Pacific coast. The Russian railroads resemble those of the United States in their long average hauls, long freight trains, and large freight cars. In the Soviet Union dependence on railroad transport is proportionately much higher than in the United States. Approximately 90 per cent of the ton-mileage of all Soviet domestic transport is rail hauled, while the corresponding figure for the United States is 50 per cent. The major differences between the two countries stem less from the greater development and efficiency of competing truck transportation in the United States than from the availability of coastwise, intercoastal, and Great Lakes transport in the United States, for which there is no counterpart in the Soviet Union.

The remaining areas of the world with a relatively close spacing of rail lines (less than 50 miles apart) are found mainly in certain agriculturally developed areas of the Southern Hemisphere, particularly the Pampa of Argentina, the populated southeastern fringe of Australia, and the Johannesburg area in South Africa. The irrigated Nile delta is an isolated region of adequate rail transport. On a railroad map loose networks of rail lines are discernible, focusing on Rio de Janeiro and on São Paulo in southern Brazil, on Mexico City, and on Santiago, Chile.

Over the rest of the world railroads are either absent or sparsely developed. Existing lines are widely scattered, and they frequently are single-track, lightweight, narrow-gauge lines with few or no signaling facilities and steep curves and gradients. Some of these lines have been engineered through incredibly difficult terrain. Examples are the lightweight lines which ascend the steep western flanks of the Andes from the Pacific coast; in places the ascent is so abrupt that the rails have no space even for sharp hairpin turns, and trains must negotiate the slope by a series of zigzags, the engine proceeding alternately forward and backward. The world depends upon lines such as these for some of its mineral raw materials; noteworthy are the lines which haul the output of the mines of Peru, Bolivia, and northern Chile to the coast for shipment to the industrial areas of the world.

Motor transport. The steady development of truck transport since its inception early in the twentieth century has deepened and extended the revolution in land transport which began with the railroad era. Trucking has made land transport more flexible than ever before, since the truck can handle small loads conveniently. Expenses of loading and unloading are less than with rail transport, and through service between points of origin and destination becomes possible. The virtual ubiquity of roads and streets in some parts of the world extends many hundredfold the length of route that can be served by rail transport; the *articulation* of truck routes is far greater than that of the densest railroad networks. For distances up to several hundred miles in North America and for shorter distances in overseas areas, trucking is actually cheaper than rail transport, due mainly to its lower terminal costs, which more than compensate for high line-haul costs. In North America the percentage of the total transport service performed by trucking has inched steadily upward year by year. Trucking has also become an extremely important adjunct to railroad transport, since motor carriers pick up and assemble goods at railroad freight stations, as well as deliver freight from incoming trains to final destinations.

Highway transport has become the most universal form of land transport. In the United States, which has a far higher total railroad mileage than any other country, the total mileage of main highways far surpasses the railroad mileage. In most other parts of the world, mileage of improved highways compares even more favorably with railroad mileage. In many areas which are only now being developed, transport modernization frequently bypasses the railroad altogether, emphasizing highway construction and air travel. Preference for highways reflects lower average construction costs per mile compared to railroads as well as anticipated traffic densities that are below the minimum densities necessary for profitable rail haulage. Highway travel can negotiate far steeper gradients—four to five times steeper than railroad main lines—together with sharper curves, and these considerations are weighty in mountainous areas.

Average truckloads in the United States surpass averages in any other part of the world. A rapidly lengthening mileage of four-lane highways, in addition to the basic network of two-lane highways, finds no counterpart in any overseas area except Europe. Heavy American trucking performs transport services which outside of North America are generally handled by railroads. American railroads have felt the effect of truck competition, particularly in those parts of the manufacturing belt where the average manufactured item is high in value and low in bulk, as in southern New England. The shorter average hauls in the densely populated Northeast further enhance the attractiveness of motor transport in precisely the area where rail traffic densities have been highest. On longer hauls, from Florida and the Gulf coast, the Great Plains, or the Far West to the industrial Northeast, truck transport primarily caters to higher value and more specialized freight.

Although highways have been constructed in practically all inhabited areas of the world outside the United States, the relative importance of highway transport varies widely, depending on the status of competing forms of transportation and the general economy of the region. Motor haulage is common all

over Europe, but due to the closely interwoven rail pattern, the flexible nature of rail operations, and the availability of coastwise and inland-waterway shipping, trucking has not developed to the extent that it has in the United States. As in the United States, however, the bus has become a formidable competitor insofar as passenger transportation over short distances is concerned.

In the Soviet Union both highway construction and the use of heavy trucking has lagged behind railroad use, particularly as a result of the long average hauls, necessary in that large country, which would make for exorbitant highway costs. In India and Japan road transport suffers from poor road systems. Many of the Indian roads are impassable during the monsoon rains. China, which did not experience the railroad-building activity of the British as did India, even yet has few railroads, except in Manchuria and the north China plain, from whence lines provide through connections with the trans-Siberian line of the Soviet Union. China's equally inadequate road system is supplemental to a primitive, nonmechanized water- and land-transport system which remains prevalent in the Yangtze Valley and southern China. Throughout Latin America, Africa, and Australia, road transport is usually subordinate to rail transport in areas of greater-than-average population density. In the frontier areas away from the main settled regions a ramifying pattern of roads, rarely hard-surfaced, sometimes graveled, and usually with sand or dirt surface, spearheads the penetration of modern transport into all parts of the inhabited world. Exceptionally, as in the case of the mineralized Katanga and Northern Rhodesia region, railroads have been drawn deep into a new area in order to expedite the outflow of a bulky commodity.

INLAND-WATER TRANSPORT

Navigable waterways within the confines of the continents are supplemental transport routes for the internal circulation of freight. When navigable waterways are deep and situated in the midst of areas with a high development of industry and commerce, they carry high traffic densities and are interlaced with land-transport routes. Bulky traffic is carried by water carrier as far as possible, but lighter freight is ordinarily routed from origin to destination via road and rail in order to save transshipment costs or from considerations of speed or convenience. In areas where traffic potentials are high and relief obstacles are not too great, canals may be dug to interconnect two river systems, or they may be built parallel to unnavigable stretches of river. A series of dams and locks may also be constructed on a river to deepen the water and improve navigability, resulting in a "canalized river."

Inland waterways are used most extensively in northwest Europe, in central and southern China, and in the Mississippi and Great Lakes-St. Lawrence watersheds of North America. It should be noted, moreover, that two of the world's rivers, the Amazon and the Yangtze, permit small oceangoing vessels to penetrate far inland, in what is an extension of deep-sea transport. Since the opening of the St. Lawrence Seaway, moreover, smaller ocean vessels also reach all major Great Lakes ports.

The inland waterways of northwest Europe form a system of rivers, canalized rivers, and canals serving particularly northern France, the Low Countries, northern Germany, and northwestern Poland. A major important artery is the Rhine, the world's most intensively used river. On the stretch of river between the Ruhr coal field and the port of Rotterdam, normal traffic densities at any point are usually in excess of 30 million tons a year. Dependence on inland waterways for the transport of heavy bulk commodities is characteristic of northwest Europe and is facilitated in part by physical factors. Relatively deep rivers, such as the Seine and the Rhine, flow in directions useful to commerce. Floods, ice, and low water seldom occur to interrupt navigation. Divides between streams are low, facilitating canal connections between navigable rivers. Moreover, this waterway system coincides in area with the economically most advanced part of the continent. Freight is moved in barges with capacities ranging up



Fig. 376. Fifteen-barge petroleum tow on the Ohio River. A single barge may have a capacity up to one million gallons.

Courtesy American Waterways Operators, Inc.

to 2,000 tons each, some moving under their own power but many traveling in tows of two, three, or more barges.

The main inland-waterway system of Europe terminates east of the Vistula river in Poland, but waterways are also found in the western part of the Soviet Union, and the Volga and Don rivers are important barge routes. Moscow is the focus of a shallower inland-waterway system. Barges can reach Moscow from five separate river systems draining to the Caspian, Black, Baltic, and White seas. The Russian inland waterways are widely spaced for the area they serve, however, and barge traffic is paralyzed by winter freezing.

Inland waterways are important in central and southern China, precisely those parts of the country where roads and railroads are inadequate for internal commerce. Barges and junks, motorized or powered by sails and poles, move on the rivers and on the myriad of canals which thread the flat floodplains and deltas of this region. Shanghai, one of the world's largest cities, receives the bulk of its food supplies via the major and minor rivers and canals which penetrate most parts of the rural areas surrounding it. Water transport penetrates into, but not through, the hill and low mountain country of southern China between the Yangtze valley and the hinterland of Canton.

On the Mississippi river system of the United States, the colorful paddlewheel steamboats of the nineteenth century have been replaced by prosaic fleets of barges propelled by modern towboats. The short Monongahela river has been one of the most heavily used waterways in the United States. Coal is barged northward from tipples along the Monongahela to coke ovens associated with iron and steel plants in the Pittsburgh area. On the Mississippi, the lower Ohio, and the Gulf Intracoastal Waterway, dug at sea level immediately back of the Gulf coast, crude-oil and refined-petroleum products are the sustaining elements of river traffic. The Illinois Waterway is of increasing significance, since at Chicago it provides the only connecting link between the Mississippi river system and the Great Lakes. In the Northeast the Hudson river is the only important inland waterway, surpassing the New York State barge and canal system, the present descendant of the Erie Canal, which connects the upper Hudson at Albany with the Great Lakes at Buffalo.

Several other river systems are important for the economy of the regions they traverse. Noteworthy is the Paraná-Paraguay system in southern South America, which carries most of the traffic moving into and out of the region between Buenos Aires and Asunción, Paraguay. The importance of the La Plata estuary for world shipping is increased by the situation of the estuary at the lower end of the Paraná-Paraguay drainage system. The Nile and sections of the Congo uninterrupted by waterfalls have great local importance for transportation.

The Great Lakes. Transportation on the Great Lakes finds no real counterpart in any other part of the world. The lakes, a legacy of the continental ice sheets, have been an incalculable asset in the economic development of the continent. Lake carriers are glorified barges, with 10 to 20 times the capacity of river barges. Rows of hatches run much of the length of the vessel and permit extremely rapid bulk loading and unloading of ore, coal, grain, or limestone. Lakeside terminals are especially designed to handle 10,000 tons or more of cargo in only a few hours. The fundamental barge-like structure of the Great Lakes carrier, permitting a high ratio of pay load to vessel weight, is unaffected by lake storms. The Great Lakes are not large enough for the development during storms of broad ocean rollers capable of breaking a barge-type vessel amidships. A stormy lake surface becomes choppy, with a comparatively small horizontal distance between wave crests, and this does not put a strain on the frame of the vessel. The Great Lakes carrier consequently profits from its size and shape by having the lowest average carrying costs in the world. Such costs are less than one tenth of a cent per ton-mile. The one major drawback suffered by Great Lakes shipping is the four months of enforced idleness each year due to the freezing over of parts of the lakes.

Two of the most important commodities of Great Lakes traffic, iron ore and grain, both move downbound, primarily from Lake Superior to lower lake ports. Cheap lake transport of ore, particularly Mesabi ore, has greatly lowered the cost of raw materials for the American iron and steel industry (Fig. 286). The lakes have likewise made possible the sale abroad at low prices of both American and Canadian wheat grown far in the continental interior. The high place of Buffalo in the national milling industry reflects lake transportation facilities. Lake oil tankers load at Chicago and Superior, Wis., and likewise move in the direc-

Fig. 377. A typical Great Lakes vessel unloading its ore cargo at Conneaut, Ohio. Note the barge-like structure of the ship. In the background is a large bulk terminal typical of those used to unload Great Lakes ships.

Courtesy Lake Carriers Association



tion of harbors in the eastern part of the Great Lakes region. This increasingly important oil traffic on the lakes represents water-borne extensions of pipeline systems coming from the Mid-Continent oil province and Alberta Province respectively (Fig. 275).

Coal traffic is the most extensive upbound traffic on the Great Lakes. Particularly from Toledo on Lake Erie, coal moves north and west to a series of coal terminals ranging from Detroit to Duluth, Minn. From Toledo and other Lake Erie ports coal also moves via the Welland Canal into Lake Ontario for Canadian destinations. The enormous importance of Toledo as a coal-shipping port is due to its direct rail connections with the large-scale mining area of southern West Virginia, where a dearth of local manufacturing permits most of the coal to be shipped out of the mining region (Fig. 240).

PIPELINES

Pipelines are the most specialized transport medium and they can carry a variety of liquid and gaseous products, but in actuality over 99 per cent of all materials moved by pipeline are either crude petroleum, its refined derivatives, or natural gas. By the simple expedient of pumping through enclosed pipe, petroleum can be transported distances of a thousand miles or more at costs of only a fraction of those of rail transport. River barges and oceangoing tankers can carry petroleum products at still lower ton-mile costs, but the straightness of pipelines compared with the more devious routes that may be necessary for barges and tankers to follow at times give pipelines over-all advantages. Profitable operation of pipelines necessitates constant pumping at or near capacity; such conditions are met by large refineries, large tank-storage farms, or sizeable oil-shipping ports. It is only in the United States, however, that a vast pipeline system is in operation. Conditions favoring large-scale pipeline construction have until now been unique to the United States (see Chapter 22 and Fig. 275).

Petroleum lines. The petroleum pipeline system of the United States forms a broad arc. It commences on the Texas Gulf coast, extends north and northwest into the Mid-Continent province of Kansas, Oklahoma, and north Texas, curves northeast toward Illinois, then extends due east to the Atlantic coast at New York and Philadelphia. Branch lines feed into this arterial system from the Wyoming segment of the Rocky Mountain province and from expanding oil fields in the lower Mississippi Valley. The California oil fields supply a completely detached pipeline system confined to that state. Oil lines are mainly 8, 10, or 12 inches in diameter, although a few substantially larger lines are now being built. They are fed by gathering lines in the oil fields, ranging mainly from 2 to 6 inches in diameter.

The basic petroleum flow is from the Mid-Continent province northeastward toward the petroleum markets of northeastern United States, where demand is far in excess of local supply. However, between the southern end of the Mid-Continent province and the Gulf coast, the prevailing direction of pumping is *southward,* apparently away from the northeastern market area but in actuality toward the oil-tanker ports on the Gulf. Costs of transporting oil from the fields of central and southern Texas to the Middle Atlantic and New England states are lower via coastwise tanker than via pipelines overland. This is true even when oil must be pumped several hundred miles southeastward to the Gulf ports for loading onto tankers, and also when petroleum products must be piped inland several hundred miles from the tanker terminals in the New York and Philadelphia metropolitan areas in order to reach parts of the Middle Atlantic and New England market. From the refineries in the New York and Philadelphia areas, petroleum products are pumped inland as far as the Pittsburgh area, where they meet petroleum products pumped overland from interior fields.

The rapidly developing Canadian oil field in Alberta Province has been brought in touch with markets by the construction of several pipelines. Of particular importance is a line running to Superior, Wis., at the western end of Lake Superior, whence water transport is used to forward the petroleum

products toward markets in eastern Canada and eastern United States. Likewise some of the oil pumped northeastward from the Mid-Continent province is transshipped to Great Lakes tankers at Chicago.

Many of the world's oil fields outside the United States are in coastal locations, where the only feasible or possible transport is via oil tanker. The oil fields of Lake Maracaibo, the Gulf coast of Mexico, Sumatra, and Borneo are all cases in point. Even where oil fields are on the same land mass as a major market area, the availability of low-cost coastwise tanker transport obviates the necessity for pipelines. The one important exception is the Near East. Several large-diameter pipelines, the longest being 1,068 miles in length, have been opened from the fields flanking the Persian Gulf to points on the eastern coast of the Mediterranean Sea in order to circumvent the trip around the Arabian Peninsula and back, 6,000 miles in length, and to avoid the Suez Canal tolls. From the eastern end of the Mediterranean crude petroleum continues its journey toward European markets by tanker. In the Near East the advantage of pipelines over tankers for the transport of petroleum between the producing fields and the Mediterranean is clearcut. It should be noted that the exceptionally large diameters of some of the lines, 30 to 32 inches, reflect anticipated large flow from very rich fields characterized by large output in small areas.

Aside from the United States and the Near East, long pipelines are rare. Most of them are found in the Soviet Union, such as the line from Saratov to Moscow, which forwards the petroleum which has been carried northward from the Baku area via the Caspian Sea and the Volga river.

Natural-gas lines. The epitome of specialization is the natural-gas pipeline. This transport medium carries nothing except invisible but highly important gas. Natural-gas pipelines have been built in the United States from the Texas-Oklahoma Panhandle gas region and the Texas Gulf coast gas fields to both Atlantic and Pacific coasts and to numerous intermediate points. In keeping with the lower density medium, gas lines are generally larger than oil lines: 26 inches is the average diameter, and one of the longest lines in the United States has a diameter of 30 inches. Construction of natural-gas pipelines in the United States increased rapidly after World War II. Accelerated pipeline construction was caused by the new importance of natural gas. In the first place, it had become feasible to shift urban domestic users from artificial to natural gas. Secondly, pipeline construction techniques had improved, reducing the cost of construction per mile. Thirdly, several large natural-gas fields had been discovered in south central United States. Finally, the rapid growth of the chemical industry created a demand for natural gas as a raw material significant for its hydrocarbon compounds.

Outside of the United States, natural-gas pipelines are confined almost entirely to Argentina, Europe, and the Soviet Union.

AIR TRANSPORT

Air transportation may prove to be even more revolutionary than railroad transportation was in the early nineteenth century. The ultimate implications of air transport cannot be foreseen at present. Air travel has already captured a large share of total long-distance passenger travel. As yet, however, the airplane is not important for the transportation of freight, except lightweight, high-value, or perishable express freight. Although air routes have an increasing freedom from the earth's surface features, the existing world pattern of air lines shows a close correspondence with existing land and sea routes, since the greatest concentrations of air terminals are within the economically advanced ports of the world.

Although total air-passenger and air-freight miles are highest in the United States and Europe, the relative importance of air transport is often greater in areas currently being developed. The airplane is aiding the motor truck in the economic development of areas in which all modern forms of transport have heretofore been absent. The difficulty, slowness, and high cost of surface transport in Andean South America encourage the flying of some types of freight which

would otherwise be hauled by road or rail.

The relative importance of the airplane is greatest in areas which are still virtually roadless. In the vast coniferous forest lands of northern Canada, for example, a number of scattered mining camps can be reached only by air; food and mining supplies are flown in, and mine output, if of sufficiently high value, is flown out. Even in such regions the long-range trend is, however, toward a gradual development of surface transport. This means an inevitable decline in the relative importance of air transport, although, with continued economic progress, the total volume of a region's air travel will increase. Under normal conditions most freight transport will be tied to the earth's surface for a long time to come.

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31

The Geographic Basis of Economic Life

For hundreds of years the people of the world lived mostly in small groups, hamlets, villages, and very small towns and made their living through the utilization of local resources. Their immediate and continuing need was to understand their own narrow environment, and their interest was largely limited to that. The major products of these small economies were those of the land, and welfare depended primarily on the agricultural productivity of that land and was ever subject to the vagaries of weather and the peculiarities of climate. Industry, too, made use of local resources, requiring manual strength and dexterity and using little other equipment. Under such conditions life was comparatively simple for the individual, but the immediate problems of providing a means of sustenance were always pressing for attention. Conditions such as these still exist in many parts of the world, especially in those areas now often referred to by a term of doubtful merit and uncertain content—"underdeveloped countries."

In the modern industrial world entirely different conditions of production and consumption prevail. There, over large areas, both production and consumption depend only partly upon local resources, with large quantities of producers' and consumers' goods coming into areas from other sections and often from halfway around the world. The need for understanding one's immediate environment and the resources at hand is always pressing, but in the areas of modern means of production it provides only part of the answer. In order to understand the economic life of a nation now, be it as large as the United States or as small as Denmark or Switzerland, one must grasp not only the geographic diversity within the country but also that of the world as a whole.

In the previous chapters we have tried to show in a general manner the nature of geographic diversity, its basic causes, and some of its consequences. Further studies of the geography of specific regions, so-called regional geographies of continents or countries, would show still more clearly the significance of geographic diversity, even within countries as small as the Netherlands

or Ecuador, for existing economic activities and future economic development.

In Chapter 2 we discussed, among other things, the basic facts of the distribution of population over the world. It is hoped that the reader can now see to what extent geographic factors are responsible for the extremely irregular distribution of mankind.

UNEVEN DISTRIBUTION OF NATURAL RESOURCES AND PEOPLE

A glance at any world population map shows that large areas of each of the continents have few people. These are the areas where lack of production (or very small production) is caused by low rainfall, low temperatures, mountainous terrain, or even overabundant precipitation. The areas of high population density are comparatively small and embrace two types of regions: (1) fertile areas with a very dense rural population, where to a considerable extent production for own or local needs is still important, such as in parts of India, Pakistan, and China; and (2) areas of highly developed modern power-machine economies. Between the areas of high density and great paucity of population lie lands of less active or potential productivity. These range from areas of considerable potentiality, where demand for land and other resources has not yet reached a high point (areas where in time people may become more numerous) to large areas where no general intensive utilization can be foreseen on the basis of our present knowledge and technical ability. Changes in distribution of population during coming decades and centuries are, of course, inevitable. At present, however, it looks as though the distribution of people is apt to become more rather than less irregular as the result of the forces set in motion by man's development of a power-machine economy.

With the development of a power-machine economy, the basic resources essential to man have been extended beyond those of the agricultural lands into the realms of metallic and power minerals. Moreover, industrial development made it possible for men equipped with machines to produce large surpluses of agricultural goods and thus to release workers for mines and factories. In the United States, for example, about 60 per cent of the population were classified as rural at the end of the nineteenth century, whereas in 1960 only 30 per cent were so classified. The high development of industry in Western Europe was facilitated by importation of surplus agricultural goods produced on fertile but cheap new lands by machine agriculture in the United States, Canada, Argentina, and Australia.

As mentioned above, modern industrialization has given rise to areas of congested population where the production of factory goods constitutes the principal economic activity. This is true especially for many sections of eastern North America and Europe, where industrial development started early, but industrial districts and even industrial regions have sprung up elsewhere in the world, as in Russia and Japan. It can be expected that, as the power-machine economy marches on, existing small industrial districts in many parts of the world will grow in size, and that in the coming decades many new ones will spring up in areas now lacking significant industrial development.

However, the basic requisites for the development of industrial districts, be they the availability of power, industrial raw materials, a large market, favorable location, or suitable workers, either singly or in combination, are such that new industrial districts cannot be expected to develop in even patterns. Here again, geographical diversity would bar any such regularity.

Diversity and regional specialization of production. Primitive society is an example of local self-sufficiency, where man depends directly upon the resources of his immediate environment, and the skills needed are those of selecting nourishing plant products, avoiding the poisonous ones, and of capturing game and fish. In that state of society man has not acquired the mechanical skill necessary to harness sources of energy outside of himself, and he has learned only to a very limited extent how to cooperate in the exchange of surpluses with others

who live in areas somewhat remote from his own locale.

As man advanced, he increased the efficiency of his methods of production of goods to satisfy his material needs. He learned how to harness other sources of energy—animals to carry burdens and pull loads and winds and streams to be utilized by means of crude windmills and water wheels. Much later man learned how to obtain energy from natural sources, and these can now be utilized efficiently to do work on a much grander scale and at much lower cost than was possible when only the labor of men and animals was available. In the industrially progressive nations man is engaged mostly in directing the energy whereby the work of production is accomplished, and his own muscular power plays but a minor role. Because of the enormous amount of energy he now has at his command, his capacity to produce goods and to transport them has surpassed the most optimistic dreams of a century ago.

However, even modern man and his machines are limited in their activities by the environment in which they operate. That man's machines and other equipment can overcome obstacles of nature to a degree beyond what was possible in the premachine era is true, but the economic limits are quite closely drawn. Man *can* produce bananas in the middle latitudes, but only at enormous cost compared with that of their production in the tropics. Excellent table grapes are produced in England, but the cost is many times as great as in the Mediterranean lands, where they are grown under favorable climatic conditions. Man could build as good railway locomotives in Florida as in Pennsylvania, but the cost would be much higher because of the necessity of transporting the raw materials from distant sources.

Even with the great technological advances which mark the modern industrial world, economic production depends to a considerable, though variable extent on fundamental factors such as geographic location, soil, climate, location of power resources, raw materials, and available markets. These factors have different relative weights in the various sections of the world and for various types of production, but none can be ignored if true efficiency of production is to be attained.

Under modern conditions production of many agricultural and industrial commodities tends to be highly specialized. Certain areas may have optimum conditions for the output of only a few products, while most other commodities needed can be produced more efficiently somewhere else. Pennsylvania and West Virginia, for example, can produce cereals and meats, but not as efficiently as can Iowa and Kansas, whereas the former two can produce certain types of heavy manufactures of iron and steel more efficiently.

If people desire to have the benefit of many commodities, they must arrange to exchange their local surpluses for goods produced elsewhere. The local self-sufficiency of preindustrial days is not possible with machine production on a mass basis; high standards of living are inseparably linked with relatively low-cost production of goods and efficient means for ready exchange.

The physical facilities for such exchange have been developed to a remarkable degree. Steamships span the seven seas and connect the continents speedily and efficiently; railways and improved highways facilitate swift overland transport; canals and rivers carry bulky and slow-moving cargoes at low cost; air navigation now reaches all parts of the earth at amazing speeds. Communication by mail, wire, cable, and radio binds the world together so closely that people at far distant points may converse upon a few moments' notice.

TRADE AS AN INDEX OF ADJUSTMENT TO INDUSTRIAL PROGRESS

Production both in kind and quality necessarily varies with geographic conditions. Thus high standards of living depend not only on production but also upon a ready exchange of goods and services, that is, upon trade.

The United States and the Soviet Union, because of their size and widely varied resources, are more nearly self-sufficient than other nations. Nevertheless, even in these

countries, the highest welfare of the citizens demands the encouragement of foreign trade. In the United States some commodities, such as coffee, tin, and nickel, must be purchased abroad because they cannot be produced from its own resources, while others, such as tea and sugar, can be produced elsewhere at a cost so much lower that to attempt to supply the entire need domestically would be highly uneconomical in practice. During much of the nineteenth century the United States was dominantly agrarian, producing large surpluses of grain, meat, and cotton to be sold abroad to pay for needed imports and interest on moneys borrowed by citizens for the equipment of expanding industries and railroads. Now, industrial capacity is so great that manufactured surpluses are available for foreign markets. However, these can be purchased only if payments can be met by the equivalent goods or services sold for use in the United States. Thus, for domestic prosperity, a ready flow of imports as well as of exports is a necessity.

The geographic basis of trade. The term *trade* implies the exchange of goods and services. It should be emphasized that the term applies equally to individuals, communities, counties, states, and nations, and that in all cases it involves giving or selling something of which there is an abundance or surplus and buying something which is needed or preferred. In cases of trade between large areas such as states or nations or even between widely separated communities, geographic factors become prominently involved, whereas trade between neighboring individuals largely ignores geographic principles and adjusts itself to the demands of immediate need or supply.

In the United States, for example, the grassy slopes of the western highlands and plains have long been the grazinglands where young cattle build much of their bone and muscle, and whence they have been shipped to the Corn Belt as "grass-feds" to be sold to farmers and stock feeders for finishing into choice or prime beef for the higher-priced market. This has long been considered a mutually profitable form of trade or exchange, based on the factors of differing natural environments and made possible by the existence of efficient railway and highway facilities. To carry on this trade, equipment for transport, i.e., railway cars or truck bodies for hauling cattle, had to be manufactured, and terminal equipment such as stockyards (receiving and loading pens) had to be constructed at a number of cities, among them Kansas City, St. Louis, Omaha, St. Paul, and Chicago.

Another illustration that emphasizes the geographic factors as a fundamental basis of trade is that of Denmark's role as a supplier of poultry products and bacon to neighboring markets in northern Europe. Denmark is a country of small farms wherein intensive production of grain and pasture products, grass, and hay serves as the basis of success for agricultural production of quality goods. The nearby industrial markets are willing and able to pay for quality. Even though she must import concentrates as feed for her livestock, Denmark can economically provide the eggs, butter, and bacon and is prepared to guarantee high quality, thus qualifying for better-than-average world prices. Here again we have differing geographic environments as the essence of international trade.

Of course, man-made regulations may be very important, too. One might well wonder, for example, what might have been the results if the territory which is now the United States had become occupied by a number of small countries, or if the states had been given rights to set customs duties. Fortunately, the writers of the American Constitution realized the importance of a minimum of artificial barriers to trade and therefore reserved to the federal government the right to levy import duties. In this manner the growth of economic restrictions upon the flow of interstate trade was effectively curbed.

In general, trade fluctuates to a greater or lesser extent with the prevailing conditions within nations as well as internationally. The causes leading to pulsations of economic activity are not always fully understood, but it seems that one fundamental principle might well be kept in mind, namely that when production falters and

recession threatens, it is unwise to hamper international trade by erecting or increasing obstacles, such as embargoes against imports, or by raising import duties. When recession threatens, it is time to encourage, not discourage, the exchange of goods or services. When economic adversity threatens the people of any state or country, improvement rather than impairment of production and trade must be the watchword if a favorable outcome is to be achieved.

THE RESPONSIBILITY OF BUSINESS TO THE PUBLIC

The exchange of goods and services is so important a factor to the general welfare of the community that business may well be considered a public trust. Cooperation is necessary for the achievement of success in our complexly organized society. The establishment of a successful business depends upon an intelligent appreciation of such factors as location, site of operation, available resources, characteristics and needs of the people to be served, and local growth conditions. In addition to geographic and economic factors, the importance of human integrity must be recognized. The pioneers along the new social and economic frontier must not only be men of courage, they must have the scientific spirit; they must ever be in search of truth and take their stand in line with the facts of social and business progress insofar as it is possible to ascertain these facts.

While recognizing the truth of the adage, "Production is the true basis of wealth," leaders in business should recognize that general and continued prosperity depends upon fair and widespread distribution of the benefits of production. Maladjustment of the machinery of distribution is as certain to produce want and suffering among innocent victims as is maladjustment of the machinery of production. On the other hand, workers should realize that the machines which enable them to produce goods in abundance and at a relatively low cost are the results of the labor of other workers. Capital is thus necessary for maintenance of efficiency and should have equal consideration with labor in order to insure justice and well-being for all. The efficiency of production is such that in times of peace men need to work fewer hours than in the past and still may have all that they are prepared to enjoy. Such a condition is indeed a tribute to the efficiency of mechanical inventions applied to the utilization of available resources.

PROBLEMS OF THE PRESENT AND FUTURE

However, as causes lead to results, and as results become causes again, so the power-machine solution to the problem of efficient production has become itself the source of a multitude of new problems—economic, social, political, and even psychological.

There are the effects of a new, heretofore almost unknown monotony of work upon man. There are the multitudinous effects of the new tendency of man to live in ever-larger urban and suburban agglomerations. There is the problem of more and more men being replaced by more complicated machines plus a few technical experts. There is the problem of whether in some parts of the world standards of living might well become so artificial as to become unhealthy—physically, morally, and mentally—for man. There is the problem of deciding whether machine-made goods can and should be given greater durability, instead of having, as now often alleged, a certain amount of "built-in" obsolescence. There are the problems resulting from rapidly changing techniques and the problems posed by the necessity of finding the power and other materials necessary to keep a power-machine economy rolling. There are the numerous problems attendant upon an ever-more-intensive utilization of agricultural, forest, and fish resources, problems which as yet may not be very evident in such countries as the United States, Canada, or Argentina, but which are very real and very pressing in such areas as India and China, and which will in time become pressing everywhere.

So one could go on enumerating the problems that have resulted from recent technical advances.

Modern techniques have brought man great advantages, but they have brought with them greater problems, even if we leave out of consideration man's newly acquired power of being able to accomplish almost total self-destruction.

What of the future? The productive genius of man has been ably demonstrated, and the necessity of the scientific spirit is clearly evident. Man's social genius is still to be proven. Man must learn to understand far better the various aspects of the natural environment in which he lives, especially climate, soils, macroflora and microflora. In fact, percentagewise we now know vastly more about the space surrounding the earth than we know scientifically about the surface on which we live. Man must search for the facts as to the qualities, kinds, and distribution of the natural resources upon which production depends. He must learn to use wisely, with true ideals of conservation, the resources which are difficult to replace or which are completely irreplaceable, such as soils, forests, and minerals. Scientific studies of the best uses of land will help to avoid economic waste and its associated hardships. But even more is needed. Man must have the courage to voice his convictions and to plan his actions in accord with facts. Intellectual honesty often requires the highest type of courage.

In the social and economic world which confronts us are problems which should fire adventurous minds with enthusiasm. There is need for the brightest and most daring minds to work unceasingly at the tasks of learning fuller truths about the material world in which we live. That, however, cannot be the final goal. Beyond lies the problem of developing greater and deeper human happiness as a reward for the increased productive efficiency. Men will have many hours daily wherein they need not toil at grinding tasks. Such hours will be theirs for the development of their higher needs. Those hours should be conducive to scholarship, literary achievement, and to the fine arts of painting, drama, and music. May those hours become, in a true sense, ennobled leisure!

Appendix

maps, map projections and time zones

MAPS

To INFORM others, or for purposes of record, man early found a need to draw simplified graphic pictures, of the lands he owned, showing boundaries and buildings, or of an area with which he was well acquainted, showing perhaps the course of a coastline, the courses of some streams, and the location of prominent mountains and important villages and towns. It was thus that the earliest maps came probably into being. So long as man limited himself in these presentations to comparatively small areas, he encountered no serious problems. However, when he discovered that the earth is not a flat body, but a globe, and when the need developed for representing larger portions of the earth on parchment or paper, he had to face two problems: how to mark beginnings and ends on a globular surface, and how to present a curved surface on a flat one.

Parallels and meridians. To mark beginnings and ends, some fixed points are needed. Since the earth rotates on what for ordinary purposes may be called a permanent axis, the terminals of this axis, known as the *poles*, provide convenient fixed points for the creation of a network of lines with which it becomes possible to fix the location of any place, and thus the termination of any area on the surface of the globe. This network consists of two sets of lines intersecting at right angles. The meridians extend in north-south directions, and they converge toward the poles and diverge toward the equator. The *parallels* extend east-west, and they are parallel, that is, any two are equidistant throughout their extent. The *equator* is a great circle, that is, a circle the plane of which passes through the center of the globe, and which divides the earth into a northern and southern half. This is the initial circle or parallel, latitude 0°, from which distances are reckoned north and south, i.e., northern and southern latitude. (See Fig. 378.) As all meridians are great circles, and thus all are similar, it was necessary to agree on an initial meridian from which to reckon distances east and west. The meridian that passes over the well-

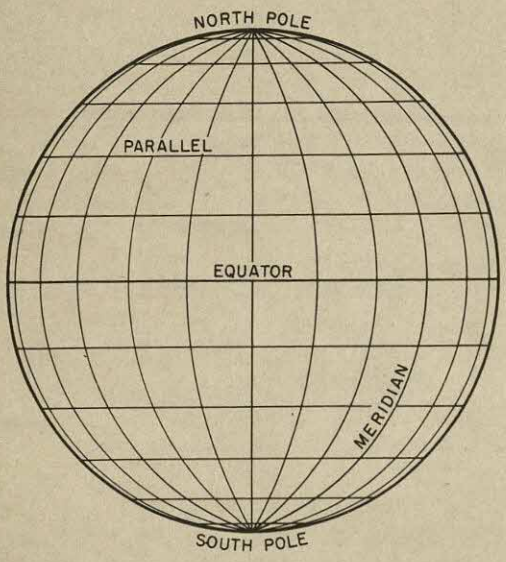


Fig. 378. Meridians and parallels, in a perspective view of the earth.

known British naval observatory at Greenwich near London was chosen by international agreement as the prime meridian, longitude 0°. From it longitude is reckoned eastward to longitude 180° E., and westward to longitude 180° W. The network of parallels and meridians thus serves to identify points on the globe. For example, Antioch, Calif., is located at 38°1′ N. and 121°48′ W, but Antioch, Neb., at 42°3′ N. and 102°34′ W.

At the same time meridians and parallels serve as the basic framework for maps. All other lines on the map, whether they represent rivers, boundaries, roads, railroads, coasts, or other features, must in any point be located correctly versus the meridian and parallels. Of course, the number of meridians and parallels is, mathematically speaking, infinite. However, on most ordinary atlas maps they are rarely drawn less than one degree apart. On a map of the United States, for example, they may be drawn 5 degrees apart, while on world maps they may be 10 or even more degrees apart. The network of meridians and parallels are the so-called *grid* of a map. The true shape, relative location, and relative length of meridians and parallels are, of course, shown only on a *globe,* and only on a globe can one see the true relative location and relative size of the continents, oceans, and details of the earth's surface. One of the problems of the cartographer is to discover ways by which to represent the curved surface of all or parts of the earth on a flat surface. Needless to say, this involves some purposeful distortion, and the nature of the distortion adopted is often most easily discovered from the shapes taken by meridians and parallels, that is, by the aspect of the map grid. Thus, no area, especially no large area, can really be represented accurately on a map. Usually the picture, insofar as area and shape of things are concerned, is most accurate near the center of a map, and toward the edges, especially in the corners, comparative areas may be smaller or larger, and shapes may be most distorted. Of course, on maps representing only an area of a few square miles, for example, the curvature of the earth is no problem, and insofar as distortion of shape and area are concerned these are of small practical importance. However, even on a map of a fair-sized county in the United States one will find that distance between meridians at the top of the map will differ a bit from that at the bottom.

The scale. All maps are necessarily smaller than the actual surface areas which they represent. To correctly interpret distances on them, it is essential to know what relation exists between a certain linear distance in actuality or "in the field," as the geographer says, and the same distance on the map. This relation is called the scale of the map. For example, if the distance between two houses is 1 mile, or 63,360 inches, and on the map the symbols for these houses are 1 inch apart, then the scale of the map is 1/63,360 or 1:63,360. The metric system, with its simple relationships between units of measurement, gives the most satisfactory map scales. If the distance between 2 crossroads is 10 kilometers (a little over 6 miles), or 1,000,000 centimeters, and this distance is represented on the map by 1 centimeter, then the scale of the map is 1:1,000,000.

If the ratio expressing the scale of a map is a small value, such as 1:10,000,000, we

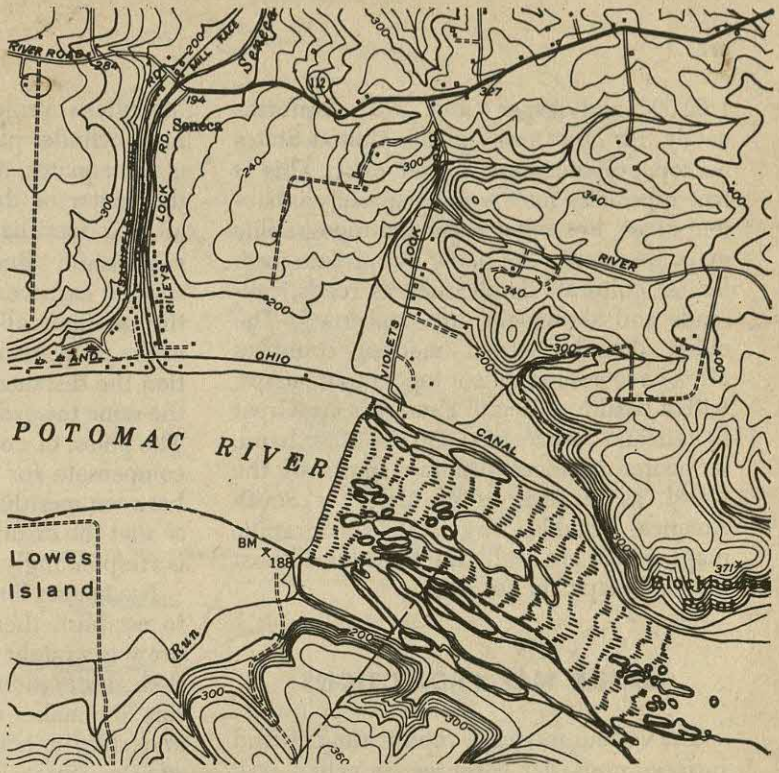


Fig. 379. Part of a topographic map. The area is located some distance above Washington, D.C., on the Potomac River.

speak of it as a *small-scale map*. If it is large, such as 1:2,500, we speak of it as a *large-scale map*. Large-scale maps show relatively small areas of the earth's surface. Small-scale maps, on the other hand, may show whole continents, or even the entire earth. The former can show much detail; the latter can show only the major features of the area represented. Also, the larger the scale, the more accurate the map can be. On a world map, for example, a very crooked river can be shown only as a simplified line, while on a map scale of 1:2,500 part of that river can be shown with all of its actual sinuosities. Most maps in atlases are small-scale maps of continents, parts of continents, countries, and so forth. Such maps are useful for reference purposes and to convey a general idea of the major features of the natural and cultural landscapes.

For practical purposes, large-scale maps, which give considerable detail and are considerably more accurate, are necessary. Of these, *topographic maps* are perhaps the most important. They are usually published by the governments of the various countries. Their scale is rarely smaller than 1:250,000 and is usually about 1:50,000 or 1:25,000. The uses of such maps are legion; in fact, no civilized country can do without a set of large-scale maps, covering at least all the important sections of the country. Topographic maps give much useful detail about differences in elevation, types of surface, distances, facts of human occupation, and so on. They used to be made by actual surveying in the field, but nowadays most of these detailed maps are made from air photographs, by so-called *photogrammetric methods*, with later field checking. This is generally done by specialized operators, who may be called by different names, such as topographic engineers, topographic geographers, photogrammetrists, etc., depending upon the country concerned. Such detailed maps are useful for military purposes, and they form a necessary basis for detailed geological and soil maps, the planning of roads, irrigation and drainage works, and the solution of many other practical problems. In some countries they are in great demand by tourists. The topographic maps of the United States are published by the Geological Survey at Washington, D.C., on various scales,

1:62,500 and larger (Fig. 379). Unfortunately, for large parts of the United States no topographic maps as yet exist. This is true especially for the more sparsely inhabited areas. For other areas the topographic maps frequently are badly out-of-date insofar as "cultural" detail, such as roads, railroads and settlement, are concerned. The older, densely settled modern countries often have very excellent topographic maps, with a wealth of detail. Examples are Great Britain and Switzerland. On the other hand, in poorer or more primitive parts of the world, as in sections of Africa or South America, reliable, large-scale topographic maps, which are really the basis for all less-detailed maps, do not exist.

MAJOR MAP PROJECTIONS

The various modes of representing curved surfaces upon flat surfaces are called *projections*. Many projections have a mathematical basis, and the resulting distortions of area and shape or angles can be mathematically determined for any portion of the resulting map. Only a few projections are discussed below.

Mercator's projection. The grid of any map projection is obtained by projecting the parallels and meridians upon a flat surface tangent to the globe. For example, with Mercator's projection we may imagine a huge cylinder placed over the globe tangent at the equator, and the map projected from the center of the globe. In this projection all the meridians are drawn as straight north-south lines, and the parallels as straight east-west lines. While on the globe, the meridians all converge to common points at the poles, on a map in Mercator's projection the distance between two meridians is the same toward the poles as at the equator. The poles, of course, are never reached. To compensate for this distortion of distances between meridians, the parallels are drawn so that the distances between them increase correspondingly toward the poles (Fig. 380).

Navigators find this projection convenient to establish their courses. They need only draw a straight line from their location to their destination, measure the angle which this line makes with a parallel or meridian, and steer a course accordingly. Although such a course is not the shortest route, it has the advantage that the same bearings can be maintained.

However satisfactorily Mercator's projection can be used in this manner, it is poorly suited for representing areas of land masses, especially those located in the higher latitudes. On this projection Greenland appears as large as Africa, whereas really it is only about one thirteenth as large. This excessive areal distortion is readily understood if one

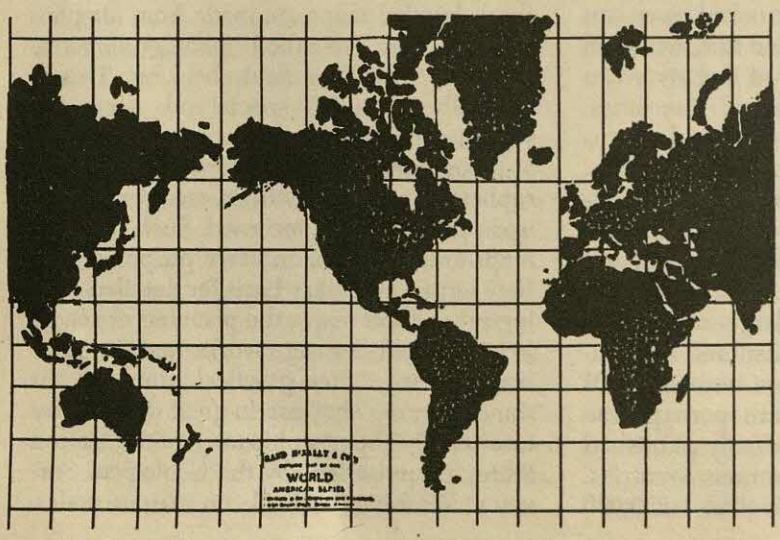


Fig. 380. Mercator's projection. Note the gross exaggeration of the size of the land areas in higher latitudes.

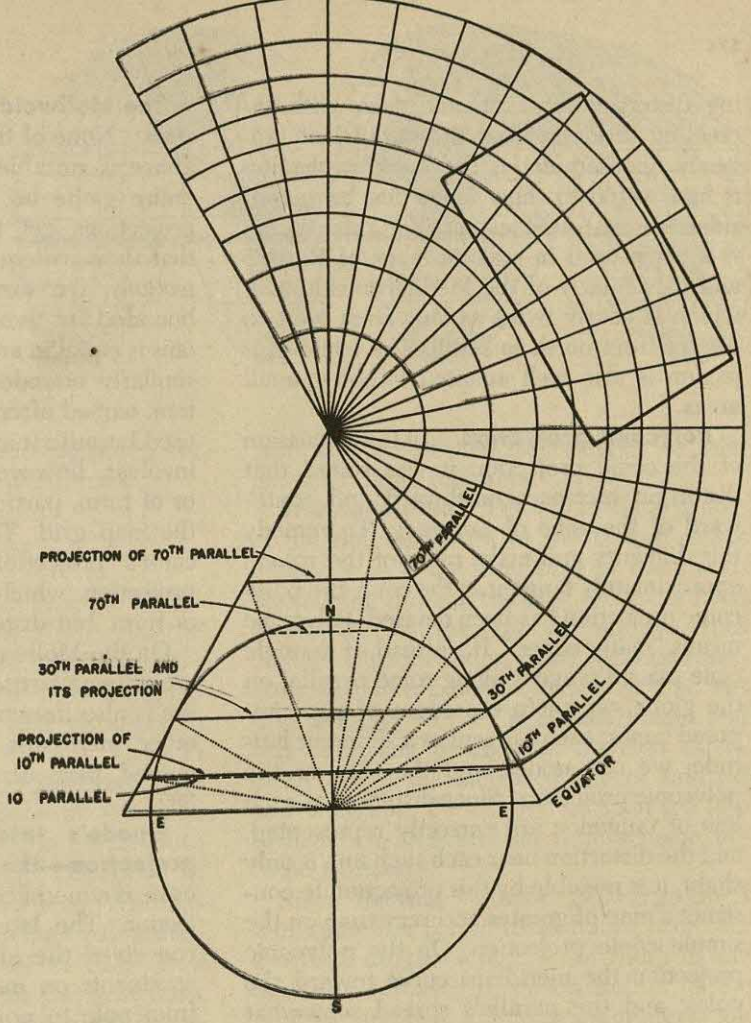


Fig. 381. The construction of a central conic projection. The rectangle shows the type of map grid obtained by using this projection. It is especially suitable for small areas and for regions which have relatively large east-west extent.

bears in mind that Mercator's projection makes all the shorter poleward parallels into lines as long as the equator, and that the parallels are spaced farther and farther apart poleward in the same manner that distances between meridians are exaggerated. The use of this projection should be discouraged for wall maps for instructional purposes.

The conic projection. The conic projection is far better suited to represent the land masses of the world than is Mercator's projection. In drawing the conic projection, use is made of the fact that part of a sphere is similar to part of a cone. If we can imagine a huge cone placed over the earth, and parallels and meridians drawn on it from the center of the globe, the resulting grid, when the cone is unrolled, would closely approximate the parallels and meridians on the globe itself within a belt not too far removed from the parallel of tangency. The meridians appear as straight lines radiating from the pole, and the parallels are represented by concentric ares about the pole as a center (Fig. 381).

The special virtue of the conic projection is that small areas may be represented with relative fidelity. In the figure the part of the cone nearest the parallel of 30° shows a corresponding area of the globe with the least distortion. East-west distance along the parallel of tangency is represented accurately. Any area mapped within a strip nearly tangent to the sphere will show little distortion in latitude. Distortion increases northward and southward from this strip. The flaring edge of the cone stretches the map in all directions, thus causing increas-

ing distortion of form and area with increasing distance from the parallel of tangency. Consequently, the conic projection is best suited to show areas that have considerable east-west extent. For this reason, it is often used in making maps of Europe and particularly of the Mediterranean area, which is nearly twice as long from west to east as from north to south. The conic projection is also well adapted to show small areas.

Polyconic projection. In the discussion of the conic projection it was stated that distortion increases northward and southward of the zone of tangency. To remedy this difficulty and make more of the sphere approximately tangent to the cone, the polyconic projection has been devised. Polyconic means "many cones." If, instead of a single cone placed tangent along some parallel on the globe, we picture a series of superimposed cones, each tangent at a different latitude, we can understand the idea of the polyconic projection. Since distances at each line of tangency are correctly represented, and the distortion near each such line is only slight, it is possible by this projection to construct a map of greater accuracy than on the simple conic projection. On the polyconic projection the meridians curve toward the poles, and the parallels spread somewhat toward the margins, thus giving to the map an appearance of bulging. The polyconic is preferred for showing large areas, particularly those with great north-south extent, as, for examples, Africa, North America, or South America.

The Mollweide homolographic projection. None of the three projections named above is suitable for representation of the entire globe on one map. Homolographic projections get their name from the fact that they are *equal-area* or *equivalent projections*. On them any given quadrangle bounded by two parallels and two meridians is equal in area to any other quadrangle similarly bounded. The Mollweide projection, named after its inventor, is extensively used because it avoids distortion of areas. It involves, however, distortion of directions or of form, particularly near the borders of the map grid. This is in contrast to Mercator's projection, a so-called *conformal* projection, which does not distort direction or form, but distorts areas.

On the Mollweide projection all parallels are drawn as straight lines. The mid-meridian is also drawn as a straight line, but the other meridians become more and more curved, particularly toward the poles (Fig. 382).

Goode's interrupted homolographic projection—the homolosine. The homolosine is a modification of the Mollweide projection. The late Professor J. Paul Goode conceived the idea of centering the larger continents on meridians which may reach from pole to pole or merely from pole to equator (Fig. 383). The spacial interruptions which occur in his projection allow a more faithful representation of the shape either of the land masses or of the oceans in the higher latitudes. On the other hand, these interruptions are objectionable in

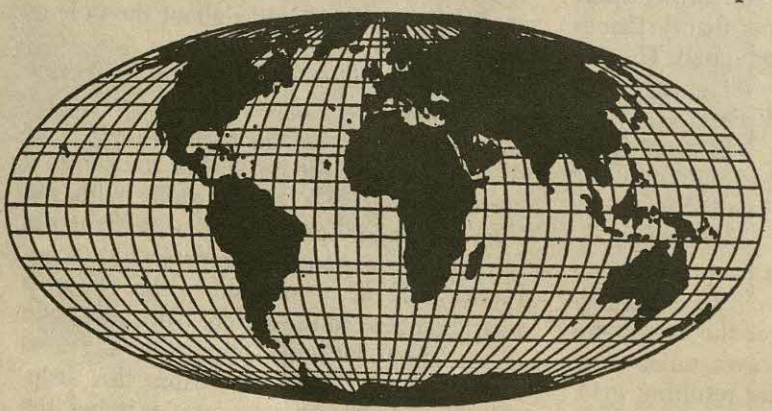


Fig. 382. Mollweide's homolographic projection of the world. An equal area projection.

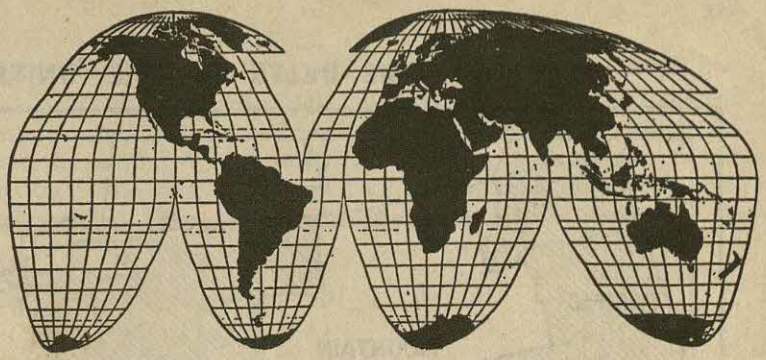


Fig. 383. Goode's interrupted homolosine projection. Compare with preceding illustration and note the better shape of the continents. (Goode Series of base maps and graphs by permission of the University of Chicago Press.)

maps to be used for certain purposes, for instance, those illustrating world trade.

TIME ZONES

The earth rotates upon its axis, the imaginary line that connects the North and the South poles through the interior of the earth. This rotation, once around in 24 hours, gives within that period light and darkness to most parts of the earth's surface. The sun seems to rise in the east, to travel across the sky, and then to set in the west. Actually, however, the earth is turning in the opposite direction, from west to east. Deception in such matters is often experienced. Who has not had the sensation of moving while seated in a train at a station, only to discover a little later that the train on the next track was slowly pulling out in the opposite direction?

Reckoning of time. The sun reaches its highest position of the day on any given meridian at exactly the same instant. That instant we call noon, and it is upon this that our time system is based. As one goes eastward, the occurrence of the noon instant comes earlier; as one goes westward it comes later. As a result, local or true sun time is different in all places located on different meridians. Toward the east the hour is more advanced, that is, it is later, for the sun has been above the horizon longer; toward the west it is earlier, for the sun has been above the horizon a shorter time. Such differences in time have many practical implications in these days of fast travel and, more especially, fast communication. In foreign trade it is often essential to know exactly what the time is at the client's office in order to make best use of cable correspondence or telephone or radio messages.

Standard Time. Prior to 1883 the people of the different cities of the United States generally used the local time of the meridian passing through the city. Since the noon instant was not the same for any two cities of different longitudes, many local time systems were in use. Such a variety of time was disconcerting to the local inhabitants and was confusing to all who traveled extensively. With the increased use of railroad and telegraph, the old system soon fell into disfavor. A standardized time scheme became necessary.

Since the sun "crosses" 360 degrees of longitude in a period of 24 hours, it crosses a belt 15 degrees longitude in width in one hour. By adopting the noon instant of the middle meridian, the maximum deviation from the true local noon does not exceed 30 minutes anywhere within the belt. This is the basis for the division of the country into standard time belts, and within them the solar time of the central meridian is arbitrarily accepted as the correct time for all places. Thus, in the United States, Eastern Standard Time is based on the meridian of 75° W. longitude, Central Standard Time on the 90° meridian, Rocky Mountain Standard Time on the 105° meridian, and Pacific Standard Time on the 120° meridian. Europe has three time belts, corresponding to our belts of standard time: Western, Central, and Eastern European time. Theoretically, such time belts should be confined strictly within 7½ degrees on either side of the standard meridian. But since population centers recognize no such boundaries, practical adjustments to problems of individual

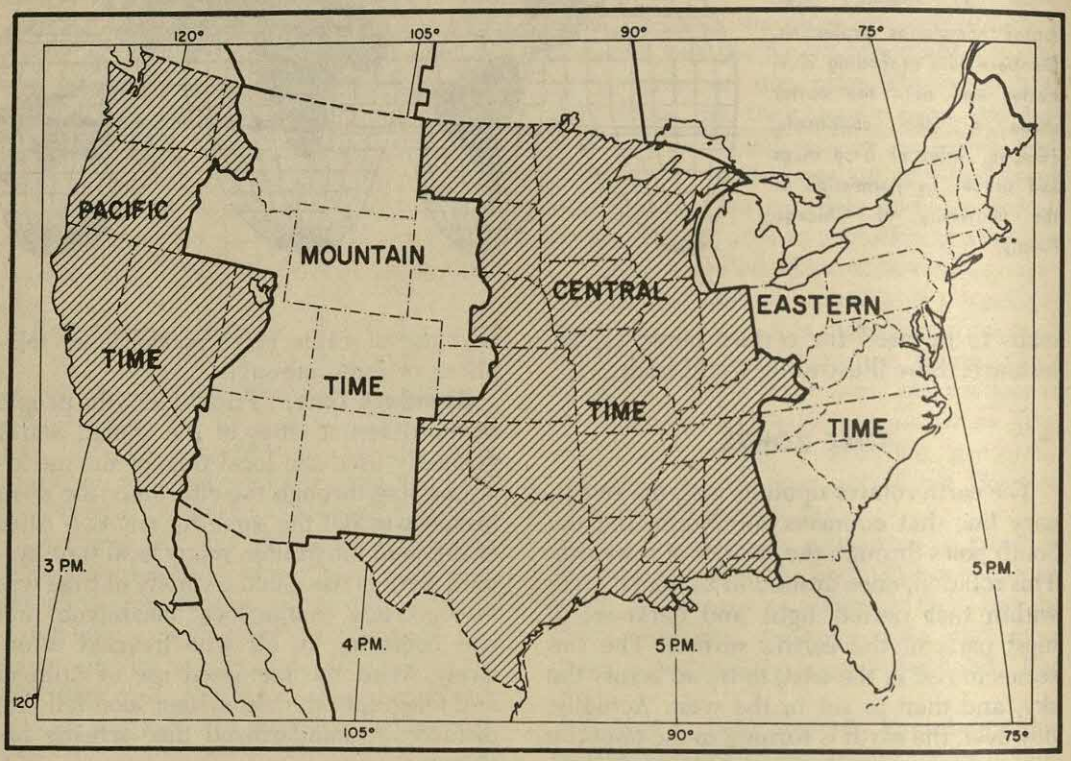


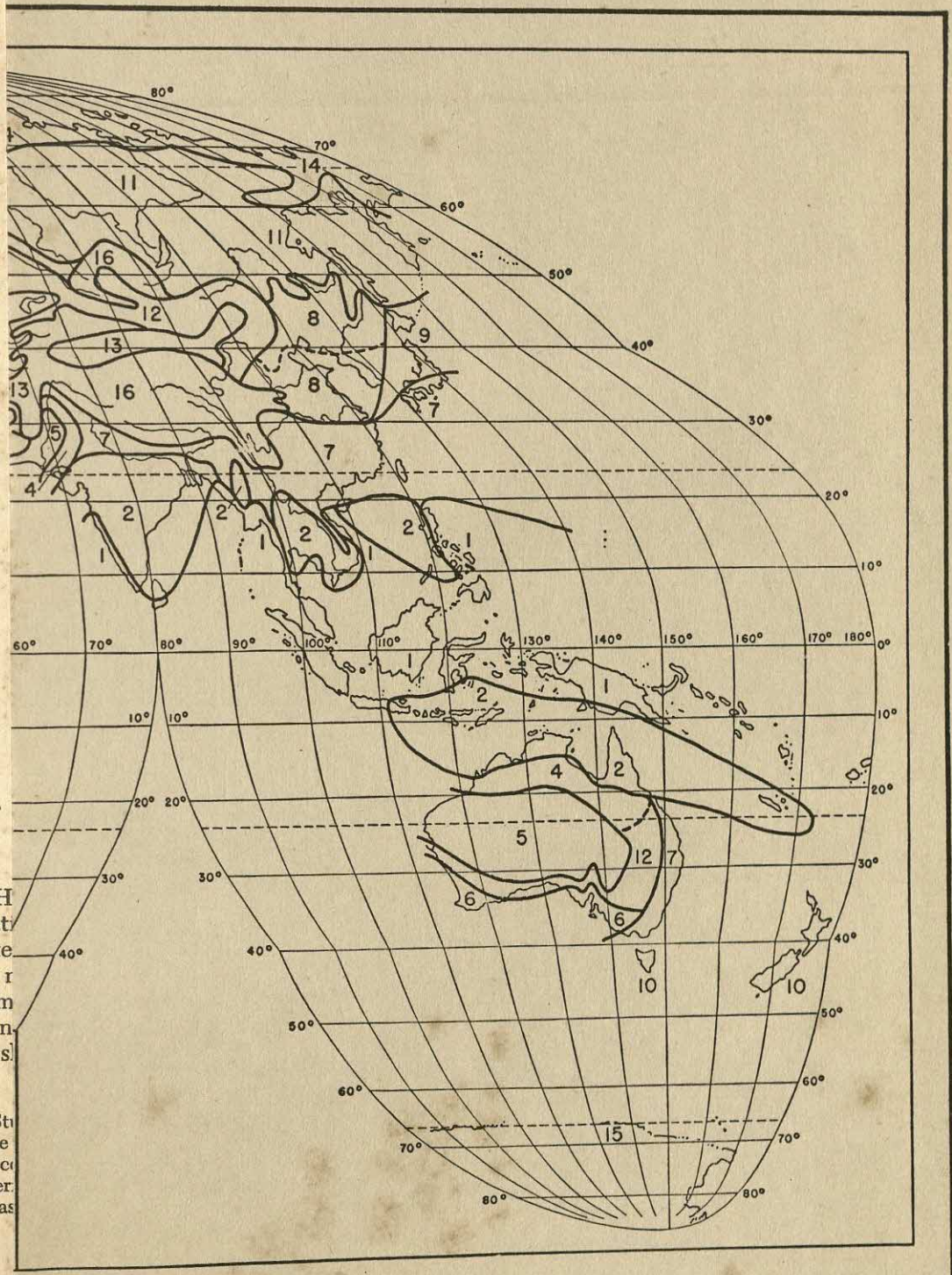
Figure 384.

cities and also to transportation problems sometimes make it necessary to set aside strict observance of the theoretical limits. Therefore, the boundaries of the time belts are irregular and only approximate the ideal (Fig. 384).

The International Date Line. The previous paragraphs have made clear that around the world different clock hours occur simultaneously. When it is noon in London, it is past noon east of there and before noon west of there. Likewise, when it is midnight in London, it is past midnight at places east and before midnight at places west. Thus when Big Ben strikes the midnight hour in London on Saturday night, places to the east have Sunday, whereas to the west Saturday still persists.

It is obvious that somewhere on earth every new date must appear first. By international agreement, the 180th meridian was chosen as the place where each new date first becomes effective. The International Date Line thus selected makes deviations from the 180th meridian only where land areas are crossed. Thus, every calendar date *first* appears on earth when it is midnight at the International Date Line. Inasmuch as the earth rotates from the west toward the east, the midnight line travels westward from the International Date Line, carrying the new date with it. Thus, just west of the International Date Line the new date appears 24 hours sooner than it occurs just east of the line. For example, when it is Tuesday west of the line, it is still Monday east of the line and will so continue until the midnight hour reaches there. Since the new date first arrives just west of the International Date Line and then proceeds westward as the earth rotates, a complete rotation, involving 24 hours of time, is necessary to bring the same date to points just east of the line. With the completion of one rota-

tion, Tuesday has been begun over all the earth, and then Wednesday is begun west of the line, and the sequence is repeated. It is well to impress firmly upon the mind that every new date first appears on earth when it is midnight at the International Date Line, and that it follows the midnight line around the world from the International Date Line westward to Japan, continental Asia, Europe, and thence across the Atlantic to New York, Chicago, San Francisco, and again into the Pacific.



Goode's Interrupted Homolosine Projection, by permission of University of Chicago Press

Index

A

Acids, production of, 517
Adobe, 7-8
Africa:
  bauxite, 481
  big game, 133
  building (*fig.*), 37
  cacao production, 143
  coffee production, 157
  colonization, 2
  copper production, 475
  date production, 178
  decreased animal life, 16
  deserts, 101
  life in forests, 37-38
  humid tropics, 100
  iron ore, 454
  landforms, 67-68
  manganese ores, 460
  milpa system, 126, 128 (*fig.*)
  oil palm production, 146-148
  peanuts, 215-217
  plateaus, 56
  population density, 133
  petroleum, 415-416
  reduction of forests, 4
  savannas, 100, 109, 130
  soils, 125
  steppes, 169-170
  subsistence hunting, 2
  travel, 9
  tropical highlands, 101, 134
  tropical rainy climate, 121
  uranium, 424
  use of cattle, 165
  urban migration, 31
  water power, 355
  weather records, 73
  zinc, 489
Agriculture:
  climate and, 14, 107, 116-118
  commercial, 3-4
  crop rotation, 262-263, 269
  cutting of forests for, 4-5
  defined, 3
  dry-land, 189
  east coast, 236
  economic influences, 105-106
  estate, 129
  expansion in United States, 330-334
  fertilizer for, 505-513
  in humid intermediate climate, 234-235
  in humid subtropics, 206-226
  increasing crop yields, 28, 505
  irrigation, 189
  livestock, 281
  machinery for, 535-537
  in Mediterranean climate, 188-200
  in mountains, 69-70
  physical environment and, 10, 106-107
  and population density, 21-23
  psychological influence, 105
  in rainy tropics, 126-130
  in semiarid regions, 175-177, 248-250
  soil and, 107
  specialization, 585
  subpolar, 242
  subsistence, 3
  in tropical highlands, 135-136
  in tropical savannas, 133-134
  use of power, 34
  in west coast marine climate, 239
Aircraft industries, 540-542
Airlines, 9, 581-582
Air pressure, as climatic element, 81-83
Alabaster, 494
Alaska:
  mountains (*fig.*), 59
  population density, 22
Aleutian Mountains, 57
Alkalies, production of, 517-518
Altiplano, 56
Alloy metals, 457-468
Alluvium, 62
Alpine System, 57-58
Alps, 54, 57-58
Altitude:
  air pressure and, 83
  classification by, 55
  effect on climate, 98-99
  temperature and, 81
Aluminum, 479-483
  in bauxite, 480-483
  uses, 479
Anatolia, 58
Andes, 57
Andesite, 53
Anhydrite, 494
Animals:
  domestic, 281-287
  as part of landscape, 15-16
  in rainy tropical forest, 125
  for transportation, 8
  in tropical savannas, 132-133
  of tropical steppes, 171-172
Antarctica:
  natural landscape, 11
  population density, 22
Anthracite coal, 365-366
  in United States, 366-367
Anticyclones, 86-87, 227
Apennines, 58
Appalachian Plateau, 56
Arabia:
  deserts, 101
  petroleum in, 6, 413-414

Arabia (*cont.*)
building (*fig.*), 36
economic activities, 36-37
population density, 22
Arfvedson, 429
Argentina:
beef production, 208
corn, 270-271
Pampa of, 109, 204, 206, 208
agriculture, 262
beef raising, 283
petroleum, 411
prairies, 109
urban move, 31
wheat production, 257, 262-263
Asbestos, 496-497
Asia:
agriculture, 22
banana production, 140
bauxite, 481
coal production, 383-384
cotton industry, 523
deserts, 103
dry steppes, 103-104
east coast climate, 103
humid continental climate, 102
industrial regions, 557
iron ore, 454-455
landforms, 68-69
manganese ores, 460
peanuts, 215-217
petroleum, 413-415
population density, 19, 22, 133
roads, 577
rubber production, 149-152
semiarid areas, 245
tropical savannas, 130
water buffalo, 128
water power, 355
weather records, 73
winds and pressure in (*figs.*), 88, 89
Atacama, 22
Atlantic Ocean:
fishing industry, 314-316
sea lanes, 564, 567-568
Atlas Mountains, 58
Atmosphere, general aspects of, 45
Atmospheric pressure, winds and, 83-88
Atomic bombs, 425-426
Atomic energy, mineral sources, 419-430
Atomic Energy Commission, 425
Australia:
beef industry, 283-284
Bindibu of, 40
climate, 100
coal, 384
colonization, 2
dairy industry, 285
deserts, 101
forests, 109
gold mining, 6
humid tropics, 100
industrial regions, 557
landforms, 69
lead, 487-488
Mediterranean climate in, 102, 183
petroleum, 416
population density, 22
raisin production, 193
semiarid lands, 170, 245
sheep, 286
steel industry, 455
subsistence hunting, 2
subtropics, 102
sugar cane, 156
tropical rainy climate, 121
tropical savannas, 130
tungsten, 467
urban move, 31
wheat production, 257, 263
zinc, 489
Austria:
population density, 19
steel industry, 451
Automobile manufacturing, 537-540

B

Bahrain, petroleum in, 413-414
Bali, 21
Balkan Peninsula, 23
Balsa wood, 164
Bananas, 138-141
commercial production, 141
disease of, 127, 129 (*fig.*)
growing conditions, 139
international trade in, 139-140
in tropical savannas, 134
varieties, 139
Barbados, 19
Barley, 272-273
growing conditions, 272-273
international trade in, 273
uses, 272
Barometric pressure, 81-83
Basalt, 50, 53
Baumé scale, 390-391
Bauxite, 480-483
Bayer process, 481
Beaufort scale, 83
Becqerel, 420
Belgium:
coal mining, 379
cotton industry, 523
industrial regions, 556
population density, 19, 22, 26 (*fig.*), 28, 39-40
steel industry, 450
zinc refining, 489
Bermuda, population density, 19
Berzelius, 429
Bessemer process, 439
Bindibu, 40
Bison, 2
Bituminous coal, 364
mining, 367-370
quality, 367
in United States, 367-370
Black Forest, 57
Bleaching compounds, 518
Blizzards, 230, 245
Bolivia:
petroleum, 411
plateau of, 56
tin deposits, 477
tungsten, 467
Bolsons, 62
Bombs, nuclear, 420-421
Bora, 185
Borneo:
petroleum, 415
soils, 125
Brazil:
campo cerrado, 132
coffee production, 157-158
cotton, 214
industry, 137
iron-ore, 448
manganese ore, 460
tungsten, 465-467
urban move, 31
Brick, 493, 494
British Guiana, bauxite in, 481
Bronze, 470
Bromine, from sea, 318
Building (*see* Construction)
Bunsen, Robert, 483-484
Burans, 230
Burma:
climate, 100
population density, 23

C

Cacao, 141-144
distribution, 142-143
disease, 127
growing conditions, 141-142
international trade in, 143-144
Caliche, 506
Camel, 178-179
Campos cerrados, 100
Canada:
air transport, 9 (*fig.*), 582

asbestos, 497
copper ores, 472-473
gypsum, 496
humid continental climate, 102
iron and steel industry, 446
iron-ore deposits, 436-437
lead, 487
lumbering, 295-296
meteorological stations, 73
nickel deposits, 463
oil pipelines, 580-581
petroleum, 403
population density, 22
rail network, 574
tundras, 109
wheat production, 257, 258-261
uranium, 423
zinc, 489
Canadian Shield, 57, 63
Canary Islands, banana production, 140
Capital:
control of oil industry, 416
defined, 7
importance for industry, 35, 332-333
Caribbean:
banana production, 139
climate, 100
Caribou, 303
Carpathians, 58
Cartography, 66
Cassava, 136
Cattle, 282-285
in arid lands, 175-176, 252
centers of production, 282-284
in Corn Belt, 269-270
dairy, 284-285
diseases of, 127-128
in humid subtropics, 207
in Mediterranean climate, 189-190
role in agriculture, 281
sacred, 164-165
in semiarid areas, 248-249
taurine, 282
tropical, 164-165
in tropical highlands, 136
types of, 282
zebu, 207, 282
Cedar, 164
Celebes, 21
Celluloid, 520
Cement, 498-499
Central America:
animal life, 133
banana production, 127, 140
forests, 109
soil, 126
tropical highlands, 134
tropical savannas, 130
Census, world, 17
Ceylon:
cinnamon from, 161
coffee in, 127
Chaparral, 187
Chemical industries, 517-521
minerals important to, 499-504
Chernozems, 113
Chile:
copper production, 473-475
iron-ore, 448
Mediterranean climate, 102, 183
nitrate, 506-507, 519
petroleum, 411
west coast, 239
China:
agriculture in north, 234
coal, 383
cotton, 214
cutting of forests, 4
fishing industry, 3, 313
humid subtropics, 203
inland waterways, 578
iron ore, 454
loess regions of, 65
petroleum in, 415
population density, 19
Si-Kiang delta, 62
soybeans, 274
subsistence farming, 3
subtropics, 102
sugar production, 153, 156
tea, 224-225
tobacco, 279
tungsten ore, 465
wheat production, 257
Chinaware, 493
Chocolate, 144
Chromium, 460-462
Cinnamon, 161
Circum-Pacific System, 57
Cities:
increase of, 29
population density, 24
Citrus fruits, 190, 194-200
lemons, 194-196
oranges, 196-200
Clay, 52, 492-493
Climate:
agriculture and, 3, 14, 116-118
as basis for trade, 14-15
classification of, 95-99
continental, 98
defined, 14
dry, 101, 103-104
elements of, 78-93
factors affecting, 73-78
humid, 99-100, 102-103
humidity and, 88-89
humid tropical, 119-136
importance of, 14-15
intermediate, 97, 102-104
major zones, 96-97
marine, 98, 103
mountain, 98-99, 104
physical comfort and, 120
precipitation and, 89-93
polar, 97, 104
subpolar, 103
subtropical, 97, 101-102
study of, 72, 95
temperature and, 81
tropical, 96-97, 99-101
tropical rainy, 121-123
unfavorable, 22
winds and, 87
Climatology, 95
Clothing:
in arctic, 37
climate and, 14
in tropics, 37
Cloves, 161
Clouds, 91
Coal, 358-385
constituents of, 361-362
distribution in United States, 366-373
early use, 358
economic position, 359-360
future, 384-385
industrial concentration near, 548-549, 556
kinds, 362-366
mining, 5-6
nature of, 360-361
from polar regions, 303
production:
in Asia, 383-384
in Europe, 377-383
in South America, 384
in United States, 373-377
in USSR, 383
strip-mining, 369-370
uses, 362
Coal tars:
organic chemicals from, 518
for dyestuffs, 519
Cocaine, 161-162
Coconut palm:
commercial production of, 145-146
growing conditions, 144-145
products of, 144
Coffee, 156-160
commercial species, 157
diseases, 127
distribution of industry, 157-159
growing conditions, 156-157
international trade in, 159-160

Coffee (*cont.*)
price control, 158
in tropical highlands, 136
Coke, 364-365
Colombia, petroleum in, 411
Colonization, 2
Colorado Plateaus, 55 (*fig.*), 56
Columbia Plateau, 54, 56
Commerce, *defined*, 9-10
Communication, *defined*, 8
Conglomerate, 51
Conservation:
of fish, 309-311
of forests, 4-5
of nonferrous metals, 469
of petroleum, 394-395, 403
of seal herds, 318
of soil, 116
of whales, 318
Construction:
in arctic (*fig.*), 36
climate and, 14
as manufacturing, 7
materials, 491-499
in tropics (*fig.*), 37, 38
Consumer goods, 7
Continental climate, east coast, 235-237
Continental shelves, 46
Copper, 469-476
early use of, 469-470
ores, 470
smelting and refining, 470-471
world production, 471-476
Corn:
in Argentina, 270-271
distribution of, 234
in Europe, 271-272
historical importance, 267
in tropical savannas, 134
types, 270
in United States, 267-270
wide use of, 265-267
Corn belt, 267-270
Costa Rica, 126
Cotton, 207-215
growing conditions, 208
historical significance, 208-209
in Mediterranean climate, 200
mule for production, 207
producers of, 209-214
trends in, 214-215
in tropical savannas, 134
types, 209
in United States, 208-212
Cotton textiles, 521-523
Cowboy, 249
Crops:
rotation, 116
temperature and, 117
Cryolite, 303
Cuba:
coffee, 159
sugar cane, 153-154
tobacco, 280
Cultural landscape, 10-11, 551-552
Curie, 420
Cyclones, 86-87, 203, 227
tropical, 131-132
Cyprus, copper from, 476
Czechoslovakia:
industrial region in, 557
population density in, 19
steel industry, 453-454

D

Dairy industry, 284-285
in Europe, 239
Dams, for water power, 341-343
Dates, 177-178
Dead Sea, 55
Decomposition of rock, 59-60
Delta formation, 62
Denmark:
dairy industry, 285
fishing, 316
population density, 19, 23
Deposition:
glacial, 62-64
by water, 61-62
wind, 64-65
Deschutes National Forest, 60
Deserts, 172-181 (*figs.*, 174, 176)
agriculture, 117
camel in, 178-179
characteristics, 173-174
date production, 177-178
intermediate, 250-252
irrigation, 22-23
life in, 179-181
middle latitude, 103
population density, 22
soils, 113, 175
use of, 175-177
vegetation, 109-110, 175, 251 (*fig.*)
warm, 101
Detergents, 520
Diabase, 51
Diastrophism, 54
Dinaric Alps, 58
Disease:
of cacao, 141-142
effect on coffee growth, 157
to lemon trees, 194
in tropics, 38, 126-128
cattle, 165
Disintegration of rock, 59
Distance, economic, 34
Doldrums, 84
Dolerite, 50
Dolomite, 484
Domestic service, 10
Dominican Republic:
bauxite, 481
coffee, 159
sugar cane, 154, 156
Drake, Colonel E. L., 388-389
Drilling:
for minerals, 6
for petroleum, 388, 393
Droughts, 3
Durable goods, 7
Dustbowl, 260
Dyestuffs, 519
Dynamo, 340

E

Earth:
atmosphere, 45
conditions for existence, 44
hydrosphere, 45-46
lithosphere of, 46
Earthquakes, 57
East coast continental climate, 235-237
Ebony, 164
Economic activities, variety of, 1-10
Economic distance, 34
Economic geography, *defined*, 42
Economics:
agriculture and, 105-106
importance of geographic studies, 41
population density and, 21, 27-28
resources and, 42
of tropical agriculture, 138
Economy, "power-machine," 35
Ecuador:
cacao plantations, 127
petroleum, 411
Egypt:
cotton, 214
petroleum, 415
Einstein, 420
Elbury, 58
Electricity:
early use of, 334
equipment for, 542-543
industry and, 553
long-distance transmission, 356
nuclear energy for, 426-427
for reducing aluminum, 481
Electronics industry, 543-545
Emigration, 29

Energy:
nuclear, 419-430
solar, 73
Environment (*see* Physical environment)
Epicontinental seas, 46
Equator:
angle of sun, 75-77
wind belt, 84
Equatorial front, 85
Equatorial wind belt, 84
Equinoxes, 76-77
Equipment, 7 (*see also* Machinery)
Erosion:
of clay, 52
defined, 60
glacial, 62-64
by gravity, 61
in Mediterranean soils, 187, 188
results of, 61
sheet, 61
water, 50, 61-62
by waves, 62
wind, 64-65, 260
Eskimos, 303, 304
economic activities of, 36-37
Estates, in rainy tropics, 129
Ethiopia, 101
Eurasia:
forests, 5
intermediate climate, 97
subpolar area, 103
European Coal and Steel Community, 380-383, 449, 556
European Economic Community:
cotton industry, 523
motor vehicle output, 540
steel production, 448, 449-451
Europe:
agriculture in, 22, 234, 239
barley, 273
bauxite, 481
beef industry, 284
cacao imports, 143-144
coal production, 377-383
coconut consumption, 146
coffee consumption, 159
copper mining, 475
corn, 271-272
cotton industry, 523
cutting forests, 4
dairy industry, 285
effect of Gulf Stream, 81
electrical industries, 543
fertilizer consumption, 505
focus of shipping, 562-564
glacial effect, 63
humid continental climate, 102
industrial regions, 556-557
inland waterways, 577-578
iron and steel industry, 448-454
landforms, 68
lead, 487
lignite deposits, 363
manganese ores, 459
marine climate, 103
Mediterranean climate, 183
oats, 273
oil palms, 148
petroleum, 411-413
population changes, 29
population density, 19
potash, 512-513
railroad networks, 574-575
rye, 265
shoe industry, 533
tobacco, 279
uranium, 424
water power development, 351-355
wheat production, 263-264
Exploitation:
of forests, 4
of minerals, 6, 324-327
of wild animals, 16
Explosives, industrial, 519

F

Factory, 33 (*see also* Industry)
Farming (*see* Agriculture)
Fault trough, 54
Fauna (*see* Animals)
Fertilizer:
chemical production of, 519
for conserving soil, 116
minerals as, 504-513
Fiber synthetics, 520
Figs, 192
Finland:
building material, 8
effect of glaciers, 63
forests, 109
nickel deposits, 463
population density, 40
Fish:
conservation, 309-311
distribution, 307
food supply for, 306-307
in polar climate, 303
shellfish, 314
stocking of, 2-3
types, 308
Fishing:
in Atlantic, 314-316
commercial, 2-3
favorable conditions, 46
inland, 2
major areas, 311-317
marketing problems, 309
methods, 308-309
in Pacific, 313-314, 316
ports for, 309
potential areas, 316-317
subsistence, 2
in tropics, 316
for whales, 317-318
Flocks, as wealth, 180
Floodplain, 62
use of, 10
Flowers, 106
Food (*see also specific crops*):
in arctic, 37
climate and, 14
as consumer goods, 7
increased production, 28
per capita, 28
prejudices, 105
in tropics, 37
Food and Agricultural Organization, 28
Forestry, 4-5
Forests, 289-299
climate and, 5
coniferous, 109
conservation of, 4-5
deciduous, 109
east coast, 236
exploitation of, 4, 290-296
humid continental, 232
in humid subtropics, 204-206
importance of, 5
Mediterranean type, 186-187
in North America, 236
northern coniferous, 290
products, 5
rain, 107
removal of, 4, 289-290
as resource, 242
soils, 113
subpolar, 241-242
subtropical, 107-109
tropical rain, 4
west coast, 238
Formosa, sugar cane production, 156
France:
coal mining, 379
cotton industry, 523
iron ore, 450
population density, 39-40
potash, 512
wheat production, 257-258, 263
uranium, 424
water power, 353
wine production, 193
Frasch, 503
Frosts, 3

Fruits:
dried, 191-194
citrus, 190, 194-200, 217-218
out-of-season, 200
subtropical, 217-218
Fuel (*see also* Coal; Petroleum):
wood as, 4
Fujiyama, 58
Furs, 243, 298-299
centers of production, 298-299
commercial raising of, 2
farming, 299
seals, 318
from tundra, 304

G

Galena, 485-486
Garigue, 187
Gas (*see* Natural gas)
Gasoline, pipeline transportation of, 407
Gaucho, 249
Geography:
different kinds of, 42
and population density, 21
Germany:
coal mining, 379-380
cotton industry, 523
industrial regions, 556
population density, 19, 28, 40
potash, 512
steel industry, 450
water power, 354
Ghana, bauxite, 481
Glacial drift, 64
Glaciation:
effect, 63 (*fig.*)
erosion by, 62-64
valley changed by, 65 (*fig.*)
Glass sand, 492
Globes, 66
Goats, 175-176, 190
in arid lands, 252-253
Gold:
from California, 333
mining, 6
Goode, J. Paul, 594
Graben, 54, 68
Grain:
durum wheat, 189
in Mediterranean climate, 189
in rainy tropics, 128
in tropical highlands, 136
in tropical savannas, 134
Granite, 493-494
components of, 50-51
Grapefruit, 217-218
Grapes, 106, 117
dried, 193
production of, 190
for wine, 193-194
Grass, in semiarid land, 246-247
Gravel, 492
Grazing (*see also* Cattle):
in arctic, 37
Great Britain:
coal production, 377-379
cotton industry, 523
industrial regions, 556
motor vehicle industry, 540
population density, 19, 28, 39-40
steel industry, 448-449
tin, 477
Great Smoky Mountains, 57
Greece:
olive production, 191
land per capita, 28
raisin production, 193
Greenland, population density, 22
Groundwater, 337, 338-340
Guinea, bauxite from, 481
Gulf Stream, effect on temperature, 81
Gypsum, 494-496
in cement, 499

H

Haber process, 519
Haiti:
bauxite, 481
coffee production, 159
Halite, 499-502
Harmattan, 171
Hawaii:
soil in, 126
sugar cane production, 154-156
volcanoes, 53
Health, 14
Heat distribution, 77-78
Hematite, 432
Highways, 576-577
Hilly lands, 56
Himalayas, 58
formation of, 54
nature of, 57
Hindu Kush, 58
History, population density and, 21
Hogs, 207-208, 286
Horses, 281-282
Hothouses, 106
Human power, 8
Humid continental climate, 229-235
characteristics, 229-232
Humidity (*see also* Precipitation):
defined, 88
characteristics of, 89
Hungary:
plains, 58
population density, 19
Hunting, 2
Hurricanes, 203-204
tropical, 132
Hydroelectric power (*see* Water power)
Hydrogenation, 391
Hydrosphere, 45-46
Hygrometer, 89

I

Iberian Peninsula, 23
Ice Age, 63
Icecap climate, 304-305
Icecaps, 104
Iceland:
lava plateau, 54
population density, 22
Igneous rocks, 50-51
Inclination of earth's axis, 75-76
India:
cattle in, 128, 164-165
coal production, 384
cotton, 212-214
cutting forests, 4
industry, 137
land per capita, 28
pepper production, 160
railroads, 575
savanna climate, 100
subsistence farming, 3
sugar cane, 153, 156
steel industry, 454-455
tea, 223-224
tobacco, 279
wheat production, 257
Indochina, 62
Indonesia:
climate, 100
coconut production, 146
coffee, 127, 157, 159
lava soil, 54
pepper production, 160
petroleum, 415
population density, 21
rubber production, 150
sugar cane, 154
tin deposits, 477
tobacco, 279-280
Industrial explosives, 519
Industrial Revolution, 330-334
Industrialization:
cultural landscape and, 551-552
population and, 584
requisites for, 584

steel as index, 455
of United States, 328-335
Industry:
chemical, 517-521
principal products, 517-520
classification of, 7
near coal fields, 548-549
concentration of, 547-552
effect of water bodies on, 14
electrical, 542-543
electronics, 543-545
heavy, 7
in humid tropics, 137
iron and steel, 431-455
leather, 531-533
light, 7
machinery-manufacturing, 533-537
manufacturing, 515-545
major groups, 516-517
importance of, 546-547
population centers and, 27-28, 550-551
in port cities, 551
power for, 548-549
principal regions, 552-557
rubber, 529-531
near raw materials, 7, 549-550
specialization of, 585
textile, 521-529
transportation equipment, 537-542
in United States, 552-556
water power for, 356
wearing apparel, 526-529
Insects:
effect on corn, 271
locusts, 172
in tropics, 38, 126-128
Tsetse fly, 127, 134, 165
Insolation, 73-75
Intermediate climate:
agricultural products, 254-287
air masses of, 227-228
crops of, 117
forests, 289-299
types of, 228-229
Intermediate arid climate, 250-252
Intermediate humid climate, 227-243
continental type, 229-235
land utilization, 234-235
Intermediate semiarid climate, 244-250
characteristics, 244-246
land utilization, 248-250
vegetation, 246-247
International Date Line, 596-597
International law, 401
International Tin Council, 479
Inventions:
important to water power, 340
for industrial progress, 333
Iran:
petroleum, 413
plateaus, 58
Iraq:
date production, 178
petroleum, 413
Iron:
distribution of ores, 433-437
kinds of ore, 432
manufacturing, 7, 437-440
minerals containing, 431-432
mining of, 5
scrap, 440
world resources, 446-455
Iron and steel industry, 431-455
alloy metals for, 457-468
in Europe, 448-454
evolution of, 437-440
in Latin America, 446-448
localization, 440-441
in United States, 441-446
Irrigation:
in cultural landscape, 11 (*fig.*)
of desert, 22-23
limitations, 106
in Mediterranean climate, 188, 189
population and, 22-23
in semiarid areas, 247-248, 249-250
for sugar beets, 276
temporary flood-water, 177
Isobars, 83
Isotherms, 81
Israel, orange production, 196
Italy:
cotton industry, 523
fig production, 192
industrial regions, 556
olive production, 191
population density in, 19, 28
steel industry, 450-451
water power, 351-353
wheat production, 257
wine production, 193

J

Jamaica:
bauxite, 481
coffee production, 159
Japan:
coal, 383-384
conservation of forests, 5
copper production, 476
fishing industry, 3, 313
motor vehicle industry, 540
population density, 19
railroads, 575
soybeans, 274
steel industry, 454
subtropical climate, 102
tea, 225
water power, 355
Java:
cinnamon, 161
fish stocking, 3
population density, 19, 40, 126
soil, 21, 126
tea, 224
Jordan Valley, formation, 54
Jura Mountains, 57

K

Kalahari, 22
Kaolin, 493
Katanga, copper, 475
Knit goods, 526
Korea:
cutting of forests, 4
water power, 355
Kuril Islands, 57
Kuwait, petroleum, 413-414

L

La Bine, Gilbert, 423
Labor:
defined, 33
as factor in production, 7, 35
population density, 27-28
Land (*see also* Agriculture; Natural resources):
content, 13
defined, 46
effect on climate, 97-98
resources, 28
use, 10
Landforms:
of the continents, 66-69
defined, 13
distribution, 54-58
external forces on, 58-65
farming of, 52-54
internal forces on, 53-58
minor, 65
nature of, 54-58
Landscape:
cultural, 11
natural, 10-11
Land transport, 570-577
Lapps, 303
Laterite, 125

Latin America:
cotton in, 214
steel industry, 446-448
Latitude, 12
Lava:
defined, 50
types of, 53-54
Lead, 485-488
properties, 485
world resources, 486-488
Leather, 531-533
Lemons, 194-196
Leveche, 185
Liberia, 454
Libya:
petroleum, 415-416
population density, 22
Lignite, 363-364
Limestone, 50, 497-499
structure of, 52
Limonite, 432
Lithium, 429-430
Lithosphere, 46
Livestock (*see* Cattle)
Living standard, 33-35
Lobsters, 314
Location, *defined*, 12-13
Locusts, 172
Lodestone, 432
Loess, 64-65
Logging (*see* Lumbering)
Lombok, 21
Longitude, 12
Lumbering (*fig.*, 5), 290-296
centers of, 292
difficulties, 290-291
important trees, 5
tropical, 163
in United States, 292-295
wood pulp from, 296-298
world trade, 296
Luxembourg, steel industry, 450

M

Machinery:
farm, 535-537
manufacturing, 533-537
metal working, 535
power, 35
Madagascar:
climate, 101
vanilla, 161
Magnesite, 484
Magnesium, 483-485
from sea, 318
Magnetite, 432
Mahogany, 163-164
Maize, 267
Malaya:
rubber productiorn, 150
tin deposits, 477
Management, 35
Manganese, 458-460
distribution of ores, 459-460
as steel alloy, 458-459
Mango, 136
Manioc, 134
Manpower, 27
Manufacturing, 515-545 (*see also* Industry)
colonial period, 328-330
concentration, 547-552
defined, 7
development in United States, 328-335
heavy, 7
importance, 546-547
light, 7
location, 7
population density, 7, 27-28
Maple sap, 236
Maps, 589-592
altitudinal, 55-56
importance, 66
projections, 592-595
scale, 590-591
uses of, 591-592
Maquis, 109, 187
Marble, 493
Marine life:
distribution, 306-307
favorable conditions, 46
Marine climate, west coast, 237-239
Matthiessen, Peter, 123-125
Mauritius, 156
Medicinal products, 161-162
coca bush, 161-162
quinine, 161
Mediterranean climate, 101-102, 182-201
agriculture, 188-200
distribution, 183
fruits from, 190-200
rainfall, 183-184
vegetation, 186-187
winds, 185-186
Mercator's projection, 592-593
Meridians, 589-590
Mesquite, 109
Metals:
ferroalloy, 457-468
mining, 6
nonferrous, 469-490
Metamorphic rock, 50, 52
Meteorology, 72 (*see also* Weather)
Mexico:
climate, 100, 101
copper production, 473
deserts, 101
lead, 487
petroleum, 403-404
sulfur, 504
vanilla, 161
zinc, 489
Migration, animal, 15
Milpa system, 126, 128
Mineral resources, 320-335 (*see also* Coal; Petroleum)
distribution, 324
exhaustion of, 325-327
importance of, 335
modes of occurrence, 323-324
nuclear energy, 419-430
and population density, 22
Minerals:
for chemical industry, 499-504
for construction, 491-499
defined, 46
of direct economic use, 321, 491-514
exploitation of, 6, 324-327
fertilizers as, 504-513
industrial metallic, 322
containing iron, 431-432
major groups, 321-322
mining, 5-6
ores, 322-323
in polar areas, 303
power minerals, 321
development of, 327-335
human slaves as power resources, 327-328
precious, 321-322
from sea, 318
Mining, 5-6 (*see also* Coal)
coal, 6 (*fig.*), 325 (*fig.*)
for minerals, 5-6
in mountains, 70
strip-, 369-370
underground, 323 (*fig.*)
Mistral, 185
Mollweide projection, 594
Molybdenum, 464-465
Mongolian deserts, 22
Monsoons, 88, 203, 231
in Japan, 235
Monazite, 429
Motor transport, 576-577
Motor vehicles, manufacture of, 537-540
Mount Everest, 55
Mount Hood, 53, 59 (*fig.*)
Mount Katahdin, 57
Mount Vesuvius, 53
Mountains:
of Africa, 67
agriculture in, 23
Asian, 68-69
of Australia, 69
as barriers, 70
climate of, 98-99, 104
economic activities in, 69-70
effect on climate, 70-71
erosion, 58-60

of Europe, 67
major systems, 57-58
nature and distribution, 57-58
of North America, 67
Norwegian, 38
of South America, 67
as symbols, 58
types, 57
vegetation, 69-70
water power potential, 344-345
Mules, 207
Musk ox, 302, 303

N

Natural environment:
cultural effect of, 38-39
effect on economy, 41-42
effect on production, 36-40
limiting effects, 35-36, 38
regional differences, 36
Natural landscape:
climate, 14-15
defined, 10-11
elements of, 12-16
landforms, 13
location, 12-13
water bodies, 13-14
Natural resources:
best use of, 42
distribution of, 584
factor in production, 35
importance, 35
utilization, 32-33
Natural gas:
fields in North America, 404
pipelines for, 407, 581
storage of, 408
Near East:
oil pipelines, 581
petroleum, 413-414
Netherlands:
agriculture, 4 (*fig.*)
building material, 8
coal mining, 6 (*fig.*), 379
cotton industry, 523
cultural landscape, 12 (*fig.*)
dairy industry, 285
population density in, 19, 22, 28, 40
Rhine delta, 62
steel industry, 450
urban growth, 29
New England, glacial drift, 64
Newfoundland, Grand Banks off, 46
New Guinea, Papuans of, 40, 41 (*fig.*)
New Zealand:
beef industry, 284
coal, 384
dairy industry, 285
landforms, 69
marine climate, 103
sheep, 286
water power, 355
Niagara Falls, 341, 342, 346
Nickel, 463
Nile valley, population density in, 18, 19, 21
Nitrates, 505-507, 519
Nomadic life, 176, 179-181
in polar regions, 303-304
North America:
climates, 96, 97
colonization, 2
dry steppes, 104
east coast climate, 103
forests, 5
glacial effects, 63
interior plains, 55
landforms, 67
marine climate, 103
oats, 273-274
semiarid areas, 244-245
semiarid steppes, 170
subpolar area, 103
subsistence hunting in, 2
North Star, 76
North Sea, fishing in, 46
Northern Hemisphere, 76-77
Norway:
effect of environment, 38
fishing, 311, 316
glaciation in, 65 (*fig.*)
water power, 353
Nuclear energy:
basic concept of, 420-421
for electricity, 426-427
mineral sources, 419-430
Nylon, 523, 526

O

Oases, 177
Oats, 273-274
distribution, 273-274
growing conditions, 273
Obsidian, 50
Ocean, 46
currents of, 81
depths of, 45, 47 (*fig.*)
effect on climate, 97-98
extent of, 46
source of water vapor, 46
winds over, 87
Ocean routes (*see* Sea lanes)
Ocean shipping, 561-569
Oil (*see* Petroleum)
Oil palm:
commercial production, 147-148
growing conditions, 146
Olives, 190-191
Oranges:
production of, 196-200
trade in, 196-197
Ores:
description, 322-323
mining, 6
Owens Valley, 54

P

Pacific Ocean:
fishing in, 313-314, 316
sea lanes, 568-569
Pacific Coast Ranges, 57
Paints, 519-520
Pakistan:
cotton, 212-214
desert, 101
land per capita, 28
railroads, 575
tobacco, 279
Pampas, 109, 204, 206, 208
Panama Canal, 567
Papaya, 136
Papuans, 40, 41 (*fig.*), 162 (*fig.*)
Paper industry, 296-298
Parallel, 589-590
Patagonia, 22
Peanuts, 215-217
Peat:
formation, 360
use, 362-363
Peatbogs, 290
Pepper, 160-161
Periodicals, economic-geographic, 43
Permafrost, 300
Personal service, 10
Peru:
copper production, 473
iron ore, 446
lead, 487
petroleum, 411
zinc, 489
Petroleum, 387-417
ancient use of, 334, 387-388
in Africa, 415-416
in Arabian desert, 6
in Asia, 413-415
chemicals from, 518
conservation, 394-395, 403
from desert, 180
economic control of, 416
in Europe, 411-413
federal concessions for exploiting, 401
fields, 396
first drilled well, 388
geographic distribution in North America, 395-404
importance, 389-390

Petroleum (*cont.*)
occurrence, 391-392
offshore drilling, 400-401
origin, 392-393
pipelines, 580-581
properties, 390-391
recovery, 393-394
refining, 391
shipping by tanker, 407-408
in South America, 409-411
tank farms, 407
transportation, 404-408
underlying sea, 318, 400-401
uses, 389
world production, 408-409
world trade, 416-417
Philippines:
chromite, 462
climate, 100
coconut production, 145-146
sugar cane, 156
tobacco, 280
Phosphates, 507-509
Physical environment (*see also* Natural environment):
agriculture and, 3, 10
building and, 7, 8
effect on mining, 6
manufacturing and, 7
relation to economic activities, 10
transportation and, 9
Physical geography, *defined*, 42
Physical sciences, geographic aspects of, 41-42
Pipelines:
natural-gas, 581
petroleum, 404-407, 580-581
Pitchblende, 303
uranium from, 420
Plains:
of Africa, 67
Asian, 68-69
of Australia, 69
coastal, 55
economic activities of, 71
European, 68
interior, 55
nature and distribution, 55-56
of North America, 67
of South America, 67
Plankton, 306-307
Plaster of Paris, 496
Plastics, 520
Plateaus:
of Africa, 67-68
agriculture in, 23
Asian, 68-69
climate, 99
nature and distribution, 56-57
of North America, 67
population density and, 22
Playas, 62
Plutonium, 428-429
Podzols, 112
Poland:
coal mining, 383
industrial regions, 556
population density, 19, 23
steel industry, 453
zinc, 489
Polar areas, 104
climates, 97, 300-305
explorers, 305
general characteristics, 300
human activities, 303-304
icecap regions, 304-305
population in, 22
resources of, 302-303
tundras, 300-304
Polar front, 86
Polaris, 76
Pole timber, 293
Political conditions, effect on agriculture, 154, 157
Polymerization, 391
Population:
dense, 19, 21-22, 26 (*fig.*)
advantages of, 24-25
problems of, 28-29
density, 20 (*fig.*)
by continent, 19
economic factors, 21, 27-28
geographic factors, 21
historical factors, 21
manufacturing and, 7
optimum, 28
personal effect of, 24
production capacity and, 39-40
sociological factors in, 19
soil and, 21-22
subsistence agriculture and, 3
technical factors, 21
urban, 24 (*fig.*)
distribution, 18-27, 584
changes in, 18, 29-31
factors accounting for, 19-23
in rainy tropics, 126, 128
in tropical savannas, 133
industry and, 550-551, 555
moderate, 23-24
rainfall and, 93
sparse, 19, 22-23, 26 (*fig.*), 27 (*fig.*)
advantages of, 25-27
world, 17-18
Portland cement, 498-499
invention of, 340
Ports:
fishing, 309
industry and, 551
Portugal:
fishing industry, 316
tungsten, 467
uranium, 424
Potash, 509-513, 519
uses, 509
world production of, 511-513
Pottery, 493
Poultry, 190, 208
Power:
on farm, 34
in factory, 33-34
industrial concentration near, 549
from nuclear energy, 426-427
for production, 35
steam, 330-334
for transportation, 8
Power resources:
preindustrial, 328-330
utilization of, 33
Prairie:
soil of, 113
vegetation of, 109
Precipitation:
as climatic element, 89-93
classification by, 96
in desert, 173
in dry tropics, 168
east coast, 235
effect of, 3
in humid continental climate, 231-232
in humid subtropics, 204
in marine climate, 237-238
measurement of, 91
in Mediterranean climate, 183-184
relation to wind belts, 91-92
in semiarid region, 246
polar, 302
subpolar, 241
in tropical highlands, 135
tropical rainy climate, 122-123
in tropical savannas, 131
in tropical steppes, 170-171
in tropics, 120
world distribution of, 90 (*fig.*), 91-92
Pressure, tropical rainy climate, 122
Primitive tribes, 40
Price controls, 158
Production (*see also* Industry; Manufacturing):
costs, 6
factors of, 35
kinds of, 36-39
power for, 33-34

regional differences in, 36-40
resources for, 42
specialization, 34, 584-585
varying capacities of, 39-40
Professional services, 10
Progress through resources, 42
Projection:
conic, 593-594
Goode's, 594-595
Mercator's, 592-593
Mollweide, 594
polyconic, 594
Prunes, 192
Psychrometer, 89
Public services, 10
Puerto Rico:
coffee production, 159
population density, 19
sugar cane production, 154, 156

Q

Qatar, petroleum in, 413-414
Quarrying, 321 (*fig.*)
defined, 6
Quartz, 47
Quinine, 161
Quotas, 156

R

Radiation, 73
Radium, 427-428
Railroads, 570-576
effect on growth, 13 (*fig.*)
electric, 9 (*fig.*)
equipment, 537
mountain barrier to, 70 (*fig.*)
physical conditions and, 9
transportation of oil by, 404
Rainfall (*see* Precipitation)
Raisins, 193
Rattan, 164
Raw materials:
industry near, 549-550
in manufacturing, 7
Rayon, 523-526
Reindeer, 281, 302, 303
taming of, 37
Relief, *defined*, 55
Resins, 164
Resources (*see* Mineral resources, Natural resources, Power resources)
Rhine Valley, 54
Rhodesia, copper, 475
Rice, 105, 117, 218-223
growing conditions, 218-219
importance, 218
in Mediterranean climate, 200
production:
distribution of, 219-220
methods of, 220-222
world, 222-223
in tropical savannas, 134
"Rim of Fire," 57
River regime, 341
Roads, 576-577
Rocks:
for construction, 491-499
decay, 58-59
formation, 49-50
glacial deposition, 63
igneous, 50-51
metamorphic, 52
nature, 47-52
permeability, 338
porosity, 337-338
sedimentary, 51-52
sialitic, 53
simatic, 53
Romania, petroleum in, 411-412
Rotation farming:
in Argentina, 262-263
in Corn Belt, 269
Rotation of earth, 77-78
Rubber, 148-152
changing importance, 148-149
cultivation, 149-152
Hevea trees, 148-149
products, 529-531
synthetic, 152, 529-531
tapping for, 149
Rugs, Oriental, 179
Rye, 265
Ryukyu Mountains, 57

S

Sahara Desert, 22, 174 (*fig.*)
description of, 174
rainfall in, 173
Salt, 499-502
necessity, 499-500
uses, 501-502
Salt domes, 399, 494, 501, 510
Salvador, population distribution, 126
Samoyeds, 303
Sand, 492
quartz in, 47
Sandstone, 494
structure, 51
Santa Ana, 185
Saudi Arabia, petroleum in, 413-414
Savanna, 100
of humid subtropics, 204
vegetation, 109
Saw timber, 293
Scandinavia, forests of, 109
Scotland:
formation of lowlands, 54
population density, 23
Sea:
distribution of life in, 306-307
economic significance of, 306-318
minerals in, 318
obtaining salt from, 500
petroleum drilling under, 400-401
potash from, 509-510
tropical, 316
Seaborg, Glenn, 428
Sea lanes, 561-569
Africa-Indian Ocean, 566-567
eastern North America, 567-568
Mediterranean-Red Sea, 564-566
North Atlantic, 564
Pacific, 568-569
Seals, fur, 318
Seasons:
heat distribution and, 77-78
precipitation and, 93
reason for, 76, 78
wind directions and, 87-88
Sedimentary rocks, 50
Semianthracite coal, 365
Semibituminous coal, 365
Selenite, 494
Shale, 52
Sheep, 175-176, 189-190, 286-287
in arid lands, 252
international trade in, 287
major producers, 286
in semiarid areas, 249
Shellfish, 314
Shelter, 37
Shields, 57
Shipbuilding, 542
Shipping:
by tanker, 407-408
ocean, 561-569
Shipping routes (*see* Sea lanes)
Shoe manufacturing, 533
Shrub vegetation, 109
Siberia:
building, 36 (*fig.*)
gold mining, 6
Siderite, 432
Siemens, 439
Sierozems, 113
Sierra Nevada, 54
Sierras, 57
Silica brick, 494
Silk, 523
Simoon, 185
Sirocco, 171, 185
Slate, 494

Slaves, 327-328
Slope:
effect on land uses, 10
steepness of, 55
Soap, 520
Sodium carbonates, 518
Sodium chloride, from sea, 318
Social geography, *defined*, 42
Social science, geographic aspects of, 41-42
Soils:
characteristics, 110-111
color, 111
conservation, 116
desert, 175, 252
development, 111-112
east coast, 236
effect on agriculture, 3
formation, 58
in humid continental climate, 232-234
of humid subtropics, 206
lime in, 113
loess, 64-65
major groups, 112-116
major regions, 114-115 (*fig.*)
Mediterranean type, 187-188
moisture, 96
nature of, 110
as part of landscape, 15
population density and, 21-22
productivity, 505
quartz in, 47
of rainy tropics, 125-126
for rye, 265
in semiarid regions, 247-248
stratification, 111
structure, 111
subpolar, 242
texture, 110
for tobacco growing, 277
in tropical highlands, 135
tropical savanna, 133
of tropical steppes, 172
volcanic, 21
west coast, 239
for wheat, 256
Solar energy, 73
Solstices, 76-77
Somalia, population density, 22
South Africa:
chromite, 462
coal production, 384
corn, 272
fishing industry, 316
Mediterranean climate, 102, 183
sheep, 286
subtropics, 102
uranium, 424
vanadium, 468
South America:
animal life in, 133
banana production, 140
bauxite in, 481
beef industry, 283
cacao production, 142-143
coal production, 384
coffee, 157-158
copper, 473-475
deserts, 101, 103
fishing industry, 316-317
humid tropics, 100
industrial regions, 557
inland waterways, 578
landforms, 67
petroleum, 409-411
population density, 133
rubber production, 148-149, 152
savannas, 100
semiarid areas, 170, 245
sheep, 286
soils, 125
steel industry, 446-448
subtropic climate in, 102
sugar cane, 154, 156
tropical highlands, 134
tropical rainy climate, 121
tropical savannas, 130
water power, 345, 355
weather records, 73
Southern Hemisphere:
climates in, 96, 97
seasons in, 76-77
Southern Rhodesia, chromite, 462
Soybeans, 274-275
Snows, 235, 238
subpolar, 241
for water power, 342
Spain:
effect of environment, 38-39
fishing industry, 316
industrial regions, 556-557
iron ore, 451-452
olive production, 191
orange production, 196
meseta of, 58
Specialization:
in agriculture, 3-4
increased production through, 33-34
as modern characteristic, 40
regional, 41
Sphalerite, 486
Sphericity, of earth, 74-75
Spices, 160-161
ancient trade in, 160
cloves, cinnamon, and vanilla, 161
distribution, 160-161
pepper, 160-161
Spodumene, 429
Sport, hunting as, 2
Standard of living, 40
Standard time, 595-596
Steam power, development of, 330-332
Steel (*see also* Iron and steel industry):
alloy, 457-458
manufacturing of, 439-440
scrap, 440
wide use, 431
Steppes (*see also* Tropical steppes):
Asian, 245
tropical, 101, 175-177
vegetation of, 109
Stone (*see* Rock)
Stone Mountain, 57
Storms:
cyclonic, 230 (*see also* Cyclones)
subpolar, 240-241
Stratosphere, 45
Streams:
erosion by, 61-62
as power source, 340-341
Subbituminous coal, 363-364
Subpolar areas, 103, 239-243
Subsoil, 111
Subtropical dry climate, 182-201 (*see also* Mediterranean climate)
Subtropical humid climate, 182-183, 202-226
agriculture, 206-226
character, 202-204
distribution, 202-203
land use, 206-208
soils, 206
vegetation, 204-206
Subtropics:
climate of, 97
crops of, 117
dry, 101-102
humid, 102
soils, 113
Sudan, cotton in, 214
Suez, 565
Sugar, world production of, 155 (*fig.*)
Sugar beets, 275-277
growing conditions, 275-276
principal areas, 276
Sugar cane, 152-156
distribution, 153-156
growing conditions, 152-153
political conditions and, 154
commercial production of, 153
in tropical savannas, 134
Sulfur, 502-504
Sulfuric acid, 518-519
Sumatra, 21
population distribution, 126
soils, 125

Sun:
effect on climate, 73-74
angle of rays of, 74-77
Superphosphate, 519
Surplus, agricultural, 3
Sweden:
building material in, 8
glacial effect, 63
steel industry, 451
water power, 353
Swine, 207-208, 286
Switzerland:
industrial regions, 556
mail delivery, 8 (*fig.*)
mountains in, 58 (*fig.*)
population density, 19, 22
water power in, 353
Synthetics:
fiber, 520
rubber, 529-531
textile, 523-526

T

Taconite, 431-432
Taiga, 241
Taiwan, tea from, 225
Talus, 60
Tanning, of leather, 531-533
Tank farms, 407
Tariffs:
effect on specialization, 41
effect on sugar production, 156
Tasmania, marine climate of, 103
Tea, 223-226
commercial production, 223-226
historical development, 223
Teak, 109
Teakwood, 164
Technology:
and population density, 21
utilization of power by, 33
Temperate zone (*see* Intermediate climate)
Temperature:
altitude and, 81
as climatic element, 81, 96
desert, 173
difference between land and water, 78-81
east coast, 235
effects of rotation on, 77-78
of humid continental climate, 229-230
in humid subtropics, 202-203
in intermediate semiarid area, 245
for life, 44
in marine climate, 237
measurement, 78
in Mediterranean climate, 184
ocean currents and, 81
subpolar, 240
in tropical highlands, 134
tropical rainy climate, 121-122
in tropical savannas, 131
in tropical steppes, 170
Tennessee Valley Authority, 347, 554
Terraces:
from floodplains, 62
hill, 188
rice, 220
Territorial waters, 401
Textiles, 521-529
as consumer goods, 7
cotton, 521-523
knit, 526
synthetics, 523
woolen, 526
Thailand:
climate, 100
population density, 23
Thorium, 429
Tierra del Fuegians, 303
Tibet, plateau of, 22, 56
Timber (*see also* Forests; Lumbering):
in humid subtropics, 205
of tropical steppes, 172
Time zones, 595-597
Tin, 476-479
sources, 477-479
uses, 476
Tobacco, 277-281
curing, 278
growing conditions, 277-278
international trade in, 280-281
in United States, 234, 278-279
Tornadoes, 231
Tractor, 34
Trade:
climatic dissimilarity and, 14-15
geographic basis of, 586-587
living standard and, 585-586
Trade restrictions, 41
Traffic routes, 560
Transhumance, 70
Transportation:
air, 581-582
cost, 559-560
development, 34
earth's surface and, 561-562
effect on agriculture, 3
effect of water bodies on, 14
equipment for, 537-542
importance, 8, 559
of iron ore, 442
industrialization and, 551-552
inland-water, 577-580
land, 570-577
means of, 8
motor, 576-577
mountain barriers to, 70
of petroleum, 404-408
physical environment and, 9
by pipeline, 580-581
railroad, 570-576
Trapping, 2
Travel (*see* Transportation)
Trees (*see* Forests; Wood)
Tropic of Cancer, 76
Tropic of Capricorn, 77
Tropical dry climate, 167-181
deserts, 172-181
general characteristics, 167-169
steppes, 169-172
Tropical highland climate, 134-136
Tropical humid climate:
agriculture, 137-166
water power potential, 345
Tropical nuts, 164
Tropical rainy climate:
agriculture, 126-130
major regions, 121
native vegetation, 123
precipitation, 122-123
soils, 125-126
temperature, 121-122
Tropical savanna climate, 130-134
cyclones, 131
native vegetation and fauna, 132-133
soils and agriculture, 133-134
Tropical steppes:
characteristics, 170-171
distribution, 169-170
flora and fauna, 171-172
soils, 172
Tropical woods, 163-165
production, 163
varieties, 163-164
Tropics:
building, 37 (*fig.*), 38 (*fig.*)
climate, 96-97, 99-101
crops, 117
dry, 101
economic activities, 37-38
fishing, 316
highland type, 100-101
population, 22-23
rainy, 99-100
savanna type, 100
Troposphere, 45
Trucking, 576-577
Tsetse fly, 127, 134, 165

Tundra climate, 300-304
conditions, 301-302
economic significance, 304
polar, 104
soil, 112
vegetation, 109
Tungsten, 465-467
Turbine, 340
Turkestan, 22
Turkey, fig production, 192
Typhoons, 132

U

Unemployment, in coal mines, 374-375, 378
United States:
agriculture, 234-235
automobile manufacture, 537-539
banana consumption, 139-140
bauxite, 481
beef industry, 283
cacao importing, 143-144
chromite, 460-462
citrus fruit production, 195, 196-200
coal deposits, 364
coal production, 373-377
coconut importing, 146
coffee consumption, 160
copper mining, 471-472
copper refineries, 471
corn, 234, 267-270
cotton, 208-212
cotton textile industry, 522
cutting forests, 4
dairy industry, 284-285
date production, 178
desert areas, 22, 101, 103
early coal mining, 359
electrical industries, 543
fertilizer industry, 505
fishing industry, 314, 316
fish stocking, 2
forests, 109
fur production, 298-299
Great Lakes traffic, 579-580
Great Plains region, 38, 245-250
gypsum, 496
hog raising, 286
humid subtropics, 202-203
industrial regions, 552-556
inland waterways, 578-580
iron-ore distribution, 433-435
iron and steel industry, 441-446
land per capita, 28
landscape modifications in, 10, 11
lead, 486
leather industry, 531-533
lignite deposits, 363
limestone, 497-498
loess regions, 65
lumbering, 292-295
magnesium, 485
manganese ores, 459
Mediterranean climate, 102, 183
meteorological stations, 73
molybdenum, 465
nickel, 463
oil palms, 148
peanuts, 215-217
petroleum distribution, 395-403
phosphate rock, 507-509
population changes, 29
population density in, 19, 22, 23
potash, 511-512
power development, 328-335
prairies, 109
preindustrial, 328-330
rail network, 571-574
rice, 221-222
rubber consumption, 152
salt, 502
sheep, 286-287
soils, 233-234
soybeans, 275
subsistence agriculture, 3
subtropic climate, 102
subtropical fruits, 217-218
sugar cane, 153, 156
sulfur, 503-504
tin consumption, 477
tobacco, 278-279
trucking, 576
tungsten ore, 465
uranium, 421-423
vanadium, 467
water power development, 346-351
west coast agriculture, 239
wheat production, 257, 258-261
zinc, 488-489
Uranium, 419-427
ores, 420
mining methods, 425
reserves, 427
properties of, 419-420
uses, 425-427
world distribution, 421-424
Urbanization, increase of, 29
USSR:
bauxite, 481-483
building material in, 8
Chernozem Belt, 109, 112
chromite, 462
coal mining in, 383
copper production, 475-476
cotton, 214
fishing industry, 313
forests, 109, 290
fur production, 298
industrial regions, 557
lead, 488
lignite deposits, 363
loess regions, 65
manganese ores, 459
motor vehicle industry, 540
oats, 273
petroleum, 411-413
polar climate, 303-304
population density, 23, 40
potash, 512
prairies, 109
railroads, 575
Siberia, 241
steel industry, 452-453
trucking, 577
tundras, 109
tungsten ore, 465
uranium, 424
urban growth, 29-31
water power, 354-355
wheat production, 257, 263-264
zinc, 489-490

V

Vanadium, 467-468
Vanilla, 161
Vegetable oils, tropical:
coconut palm, 144-146
importance of, 144
Vegetables:
out-of-season, 200
subtropical, 217
Vegetation, native:
climate and, 107
desert, 109-110, 175, 251 (*fig.*)
in dry tropics, 168-169
east coast, 236
forests, 107-109
formations of, 107-110
in humid continental climate, 232
in humid subtropics, 204-205
jungle, 123 (*fig.*)
Mediterranean type, 186-187
on mountains, 57, 69-70
of the Pampa, 262
as part of landscape, 15
polar, 302-303
prairies, 109
precipitation and, 93
in rainy tropics, 123
relation to soils, 107
savannas, 109
semiarid, 246-247

shrub, 109
steppes, 109
subpolar, 241-242
in tropical highlands, 135
in tropical savannas, 132
of tropical steppes, 171-172
tundra, 109
west coast, 238-239
Venezuela:
iron ore, 446
petroleum, 409-411
savannas, 132 (*fig.*)
Vietnam, climate, 100
Volcanic ash, 53
Volcanoes:
in Circum-Pacific System, 57
cone of, 53 (*fig.*)
land formed by, 53-54
Mount Hood, 59 (*fig.*)
soil from, 21
von Liebig, Justus, 509

W

Wahl, A. C., 428
Walachia, 58
Wales, 19
Water:
conservation of, 339-340
cycle of, 46
ground-, 338-340
for irrigation, 22-23
maintaining supply of, 339-340
territorial, 401
from wells, 338-339
Water bodies, influence of, 13-14
Water buffalo:
importance, 282
for rice production, 220
use, 164
Water masses, climate and, 97-98
Water mills, 328-330
Water power:
in Africa, 355
in Asia, 355
cost of, 356-357
dams for, 341-343
in Europe, 351-355
development in United States, 346-351
favorable river conditions for, 340-341
for industry, 356
mechanics of development, 341-343
streams as, 340-341
world potential, 344-345
Waterways, inland, 577-580
Wearing-apparel, 526-529
Weather:
effect on agriculture, 3
effect on airlines, 9
effect of mountains on, 70-71
elements of, 78-93
element of climate, 14
forecasting, 73
major factors affecting, 73-78
study of, 72
Weathering:
chemical, 60
in desert, 175
nature of, 58-59
Wells:
artesian, 339
water from, 338-339
West coast marine climate, 237-239
Westerlies, 85-86
Whaling, 317-318
Wheat:
in Argentina, 262-263
in Australia, 263
in Europe, 263-264
as food, 255
growing conditions, 255-256
international trade in, 265
in North America, 258-261
principal regions for, 257-258
in Russia, 263-264
in semiarid regions, 248
species, 255
yields, 264
White Mountains, 57
Whitney, Eli, 208
Wildlife, 15-16
Wind belts, 84-87
precipitation and, 91-92
Wind rose, 85 *fn.*
Winds:
anti-trades, 85
bora, 185
as climatic element, 83
cyclones, 86-87
in desert, 174
direction of, 83-84
in dry tropics, 168
east coast, 235
effect on climate, 87
equatorial front, 85
erosion by, 64-65
harmattan, 171
hot, 231
hot dry types, 185
in humid continental climate, 230-231
in humid subtropics, 203-204
on maritime climate, 237
in Mediterranean climate, 185-186
mistral, 185
over oceans, 87
prevailing westerlies, 85-86
seasonal changes in, 87-88
semiarid, 245
sirocco, 171
subpolar, 240-241
subtropical highs, 84
trade, 84-85
in tropical highlands, 135
tropical rainy climate, 122
in tropical savannas, 131-132
in tropical steppes, 171
velocity, 83
Wine industry, 193-194
Wolframite, 465 *fn.*
Wood:
as building material, 8
tropical, 163-165
uses, 4, 5
Wood pulp, 296-298
Woolen goods, 526
Working hours, 33
Wright, Wilbur and Orville, 540

Y

Yellow fever, 38
Yucatan, 126

Z

Zanzibar, cloves from, 161
Zebu, 164, 165, 282
Zinc, 485-486, 488-490
properties of, 485
world resources, 488-490